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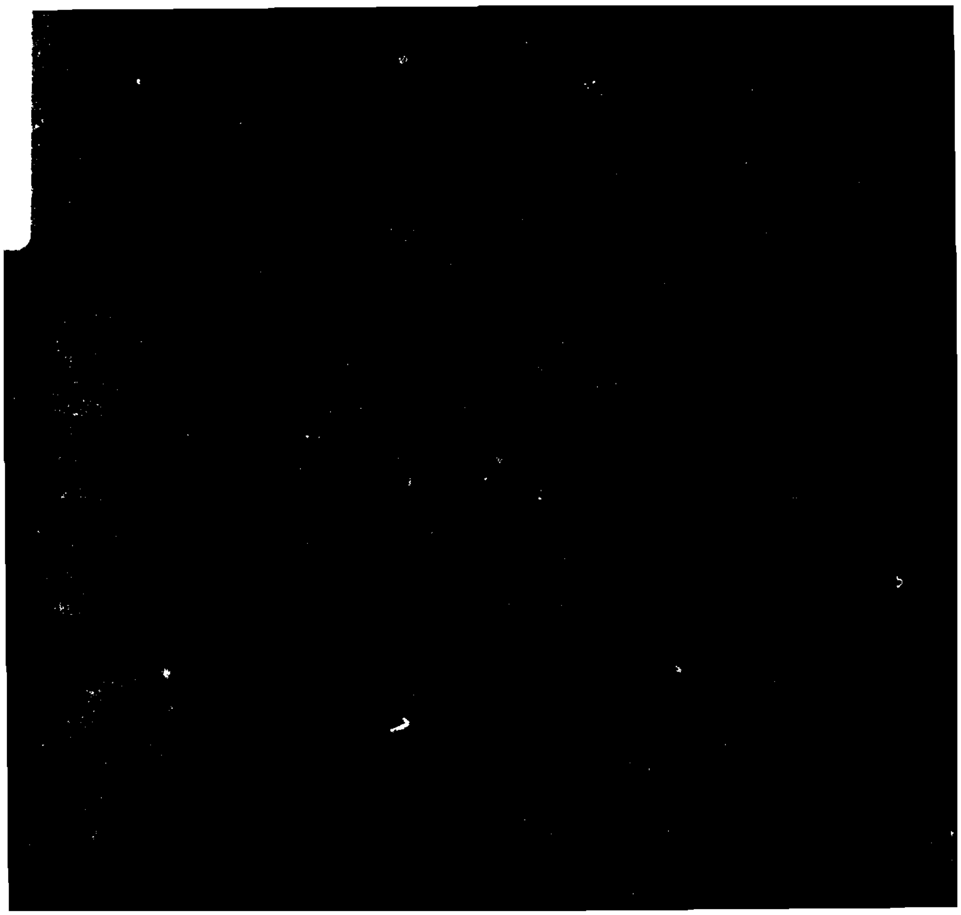

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WHOI-81-15

A SUMMARY OF WOODS HOLE BUOY GROUP MOORED STATIONS FOR THE POLYMODE PROGRAM

by

Keith F. Bradley

WOODS HOLE OCEANOGRAPHIC INSTITUTION
Woods Hole, Massachusetts 02543

March 1981

TECHNICAL REPORT

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Approved for Distribution:

Valentine Worthington, Chairman
Department of Physical Oceanography

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ABSTRACT

The Woods Hole Oceanographic Institution Buoy Group's field work for the international POLYMODE program consisted of deployment and recovery of seventy of the seventy-eight program moorings on eight research cruises. The mooring program consisted of four distinct experiments conducted from June of 1974 to November of 1979. A brief description of the arrays is provided, the mooring design process for a typical POLYMODE mooring is explained, and brief summaries are given of the WHOI deployment and recovery cruises. Appendix I is a schematic presentation of the chronological mooring history; Appendix II lists details of the seventy WHOI moorings deployed in the POLYMODE program and Appendix III lists details of other WHOI moorings that may be of interest to investigators.

A SUMMARY OF WOODS HOLE BUOY GROUP MOORED STATIONS FOR THE POLYMODE PROGRAM

by

Keith F. Bradley

Introduction

The POLYMODE program was an international cooperative project built upon the results of the Mid-Ocean Dynamics Experiment (MODE) and the U.S.S.R POLYGON project. The moored-instrument field program consisted of four distinct deep-ocean experiments conducted over five and one-quarter years. The Moored Array Project (Buoy Group) of the Woods Hole Oceanographic Institution (WHOI) participated in each experimental array by designing, building, setting and recovering seventy of the seventy-eight U.S. moorings.

This report is restricted to those moorings designed, set and recovered by the WHOI Buoy Group. An overview of each of the four experimental arrays is presented to illustrate the growth of the program over the five-year period. A review of the mooring design process indicates the detailed effort that was used to insure satisfactory placement of instruments within each array and to insure their survivability. A summary of each of the eight WHOI deployment and recovery cruises illustrates the activities involved and coordination required for successful ocean field work.

A chronological history of the mooring program in schematic form is presented in Appendix I. Mooring positions, dates of deployment and recovery and instrument type and placement depth are given in Appendix II. Appendix III lists other Buoy Group moorings deployed near the various arrays during the POLYMODE field programs. These moorings, although not part of the POLYMODE experiments, may provide additional data to investigators of the deep-ocean.

Many scientific and technical papers have been published concerning the POLYMODE program. A complete listing of these is available from the POLYMODE Executive Office, Building 54-1418, Massachusetts Institute of Technology, Cambridge, Massachusetts, 03129, U.S.A. The brief descriptions below of each array contain some references to appropriate scientific publications.

Mooring Array I

The first step in extending the research program from the work done in MODE was the deployment of the POLYMODE Array I moorings. In the last field program of the Mid-Ocean Dynamics Experiment, MODE-1, seventeen moorings with eighty-three current meters and sixty temperature/pressure recorders were on station for three to four months. The array, centered at 28° N., 69° W. emcompassed a 200 kilometer radius circle.

Expanding upon these initial measurements the POLYMODE Array I moorings (Station 542 through 550) were deployed in an inverted-T formation east of the MODE-1 center along 28° N. Latitude and north along 60° W. longitude (see Figure 3) The time on station was extended to nine months from the four months of MODE-1 with deployments in late July of 1974 and recoveries in April of 1975. This work was conducted on WHOI research cruises R/V CHAIN 116 (Heinmiller, 1974) and R/V KNORR 49. This nine-mooring array consisted of thirty-three current meters and twenty-three temperature/pressure recorders. Unfortunately two of these moorings (the northernmost and one of the triad at the eastern terminus) were not recovered due to suspected acoustic-release failure. Since the Array I moorings were recovered on the same cruise that set Array II, instrument data was not available to influence the Array II location or instrument placement. A number of scientific publications have been written detailing the goals of Array I and analyzing the data recovered (McCartney, Worthington and Schmitz, 1978; Richman, 1977; Schmitz, 1976; Schmitz, 1978; and Spencer, Hills and Payne, 1979).

Mooring Array II

The moorings of POLYMODE Array II represent the largest single array of longest duration that the Buoy Group has undertaken. The goal was a data record span of at least two years for the twelve mooring sites comprised of thirty-six current meters and twenty-three temperature/pressure recorders. Since the maximum endurance of a single mooring at that time was estimated to be about one year, three separate settings of the array were planned to fit ship schedules and instrument availabilities. The result was a total of thirty-nine moorings, one hundred twenty-four current meters, sixty-nine temperature/pressure recorders and an inverted echo sounder deployed during the array's lifetime; all moorings were successfully recovered.

The first setting of Array II in April of 1975 was conducted on research cruise R/V KNORR 49. The array plan, somewhat like a cross, was initially planned to have the north/south axis along 57° W. However, due to rougher bottom topography than expected the decision was made at sea to move it to 55° W. The general layout was followed as planned except that mooring position #6 was moved somewhat westward from the axis along 36° N. again due to topography. The four northernmost moorings were instrumented only at the 4,000 meter depth level since this area was known to be frequented by Gulf Stream excursions and it was judged that a tall intermediate mooring would either not survive the high-current velocities of the Gulf Stream or produce highly degraded measurements due to large instrument dip and tilt. The ship tracks (Figures 4, 5, 6 and 7) include the mooring locations for Array II. The twelve moorings of the first setting are Moored Stations 557 through 568.

The second setting of Array II, Stations 573 through 584, was conducted on research cruise R/V CHAIN 129. These moorings, instrument numbers and placements were duplicates of the first setting. All the initial moorings were recovered although one current meter was lost when the mooring cable became fouled in the ship's propeller during recovery.

After preliminary data analysis of the instruments recovered from the first Array II setting investigators modified the array plan by adding three moorings to the third setting. More current meters were now available from the Buoy Group shop and a moored inverted echo sounder had been developed. The third Array II cruise (R/V KNORR 60) recovered the second setting and set fifteen moorings, fifty-two current meters, twenty-three temperature/pressure recorders and the inverted echo sounder (see Figure 6).

A cooperative effort with the USSR mooring program took place during Array II. Two Buoy Group current meters were placed along with Soviet instruments on a short-term Soviet surface mooring. This was moored about five kilometers east of Array II, mooring #5 (Station 581) by Woods Hole personnel from the Soviet Research Vessel VERNADSKY. The surface-mooring float contained a U.S. supplied transmitter so that should the mooring part and the float drift away it could be tracked by satellite and recovered. Two other Soviet

moorings in the area completed a small triangle of stations adjacent to Station 611 which replaced Station 581. Data comparisons were later made between the many instruments.

Research cruise R/V KNORR 66 recovered the third setting during June and July of 1977. The twenty-seven months of records generated represent one of the largest single-array data sets from any ocean in terms of continuous time on station and number of instruments utilized. Many investigators have analyzed these records (Fedorov and Pavelson, 1980; Schmitz, 1977; Schmitz, 1979; and Tarbell, Spencer and Payne, 1979) and various aspects of this work will continue for some time.

Mooring Array III

Three groups of moorings comprised the POLYMODE Array III effort. Two of these, Clusters A and B, were managed by the Woods Hole Buoy Group while the third, Cluster C, was designed, prepared and recovered by the mooring group at Nova University. The location of Cluster B in the Atlantic Western Basin provided not only more information on eddies further away from the Gulf Stream but added the affects of the Mid-Atlantic Ridge topography to the picture. Cluster A on the east side of the Ridge was in a generally unexplored region investigating questions such as the shadowing of the eastern basin from the west and the possible energy transfer in that area. The location of Cluster C in the area of 15° N., 54° W. was chosen in an attempt to discover if the North Atlantic Equatorial Current might be another source of eddies.

The moorings of Clusters A and B were deployed astride the Mid-Atlantic Ridge on research cruise R/V KNORR 66 in June of 1977, B to the west and A to the east. Each cluster contained five moorings, fifteen current meters and thirteen temperature recorders. A cross-shaped mooring plan was designed but the rough topography necessitated on-the-scene revision to that shown on the ship's track (Figure 7). Clusters A and B were recovered on research cruise R/V ATLANTIS II 100 in May of 1978 and one site mooring at each cluster's center was deployed. The site moorings were subsequently recovered in October of 1979 on research cruise R/V KNORR 75. Total array occupancy for these two clusters and site moorings was thirty months. The site mooring at Cluster B (Station 648) established a continuous on-site Buoy Group record of 515 days, over seventeen months.

The four moorings of Cluster C consisted of twenty current meters and twelve temperature/pressure recorders. Set in May of 1979 under the direction of Mr. Philip Bedard and Dr. Peter Niiler from the University of Miami's Research Vessel GILLIS they were recovered successfully a year later on the Texas A & M University's Research Vessel GYRE. The mooring designs, equipment and techniques were very similar to those used by the Woods Hole Buoy Group.

The scientific publications of the Array III data aquisition field program explain in detail the specific goals of the various clusters and their relationships to each other. The data analysis will continue for some time but some authors have already presented their analyses of specific areas of interest (Ku, Keffer, Niiler and Wunsch, 1981; Keffer, 1981; Keffer and Niiler, 1981).

Local Dynamics Experiment array

The finale of the five-year POLYMODE field program took place with the Local Dynamics Experiment (LDE) array. The previous arrays, including the MODE program, examined ocean areas hundreds of miles in extent and long-term data sets were high priority. The LDE examined an area tens of miles in size and although the current measurements took place for over a year to develop long-term statistics a detailed study was conducted over a brief two-month span. This multi-ship operation included extensive shipboard profiling, SOFAR float work and moored profilers in an area well known for its eddy activity. In fact, the final array position was chosen at sea based upon an XBT survey that indicated an eddy-like feature should move through that location.

The Woods Hole Buoy Operations Group contribution to this array was that of designing, deploying and recovering the ten moored stations, numbers 638 through 647. Consisting of thirty current meters and nineteen temperature/pressure recorders the deployment period was to be thirteen months but due to ship scheduling was extended to fifteen months. Research cruise ATLANTIS II 100 set the array in April of 1978 and the moorings were recovered on research cruise OCEANUS 66 in July of 1979. One mooring, LDE #10, was not recovered. It is believed to have been prematurely released before the planned recovery by unknown causes.

Since this is the last and most recent large POLYMODE array completely recovered the data sets have not been completely analyzed. However, some of the initial results have been published (Brown and Owens, 1981; Owens, Luyten and Bryden, 1981) but they are not the closing chapters of the POLYMODE program.

POLYMODE Intermediate Mooring - Description and Design

Table I illustrates the improvement in mooring survivability from the MODE experiment in the early 1970's through the conclusion of the POLYMODE experiment in late 1979. Critical points in the evolution of long-term deep-ocean moorings include the departure from the use of surface moorings, the changeover to nearly complete use of wire mooring cable, the development of an easy to use computer program for accurate mooring design and increased reliability of acoustic releases for long deployments. The table indicates that as confidence in the mooring system grew deployment times improved. Although the percentage of instruments lost increased slightly (mainly due to the loss of one highly instrumented mooring) the potential number of data records escalated by a factor of 3.75 while the average deployment time nearly tripled.

MODE and pre-MODE experience indicated that surface moorings presented many survival risks from both the added stresses to the mooring due to wave action and dangers of ship collision, tampering or theft. The subsurface intermediate mooring concept eliminated these problems but added those of relocation, recovery and the need for precise mooring design and construction to place instruments at required depths with reference to the ocean bottom. The transponding acoustic release produced by EG&G Sea-Link (formerly AMF Sea-Link) provided a reliable anchor release and communication/locating ability. Synthetic mooring cables such as Dacron and nylon although light in weight are vulnerable to easy damage either in handling or by fish attack; their inconsistant stretch under load (from lot to lot or after previous use) made exact instrument placement extremely difficult. The polyethylene jacketed galvanized steel cable solved this problem albeit at increases in both cost and weight. Finally, a computer mooring design program (labelled NOYFB [Moller, 1976]) was written at WHOI for use ashore and at sea allowing rapid design and modifications to intermediate and bottom moorings. It included such pertinent features as stretch factors of wire and line, automatic instrument placement at required depths, engineering parameters and mooring motion analysis under an applied current flow.

Table I

	Moorings Set	Lost	% Lost	C.M Set	Lost	% Lost	Total Mooring Days*	Average Mooring Days	Potential** Current Meter Days
MODE	44	2	4.55	153	3	2.00	4,588	109	16,350
POLYMODE	70	3	4.29	223	13***	5.80	19,565	292	61,320

* Does not include lost moorings

** Assumes 100% performance of instruments recovered

*** Six lost on one mooring

Figure 1 is a schematic representation of POLYMODE Moored Station 609. Deployed midway through the program it illustrates the refined design techniques used in all the POLYMODE moorings. The design process is initiated with the inputs of the scientists; instrument types, instrument static depths, water depth and anticipated currents are supplied. Figure 2 depicts the uni-directional current profile to which all the moorings were designed. Other profiles were applied and results analyzed in addition to this standard profile. After an initial sketch of the station design using rough estimates for mooring line lengths and estimated buoyancy and anchor requirements computer analysis begins.

WHOI computer program NOYFB is used for all static and dynamic design. An initial static (no current) design is developed using the computer to establish line lengths, amount of buoyancy and anchor weights, all with reference to a specific ocean depth and exact instrument placement. Buoyancy is distributed in an attempt to maintain nearly constant 2,000 pound line tension (the working load of 3/16" wire rope). A section of the mooring line between the deepest instruments is designed to be adjustable in length, its final length determined at sea based upon the exact depth at the mooring site. Back-up recovery flotation is placed near the bottom so that if the mooring were to part anywhere along its length the anchored portion may be recovered later. (The utilization of this feature was not required during POLYMODE.)

After the static analysis the design current profile is applied using the computer and the associated anchor drag force and instrument dip and inclination are investigated. By selectively redistributing some of the buoyancy optimum dynamic mooring performance can be achieved without sacrificing the mooring's strength or recoverability. In the case of Moored Station 609 with the standard design current profile maximum instrument dip from the static position was less than 10 meters, inclination was less than 5° and anchor drag force was less than 200 pounds.

The question of possible anchor movement when greater than anticipated currents occur needs to be answered. The general guideline has been to use a coefficient of friction between the anchor and the ocean bottom of approximately 0.5 to determine if the anchor would

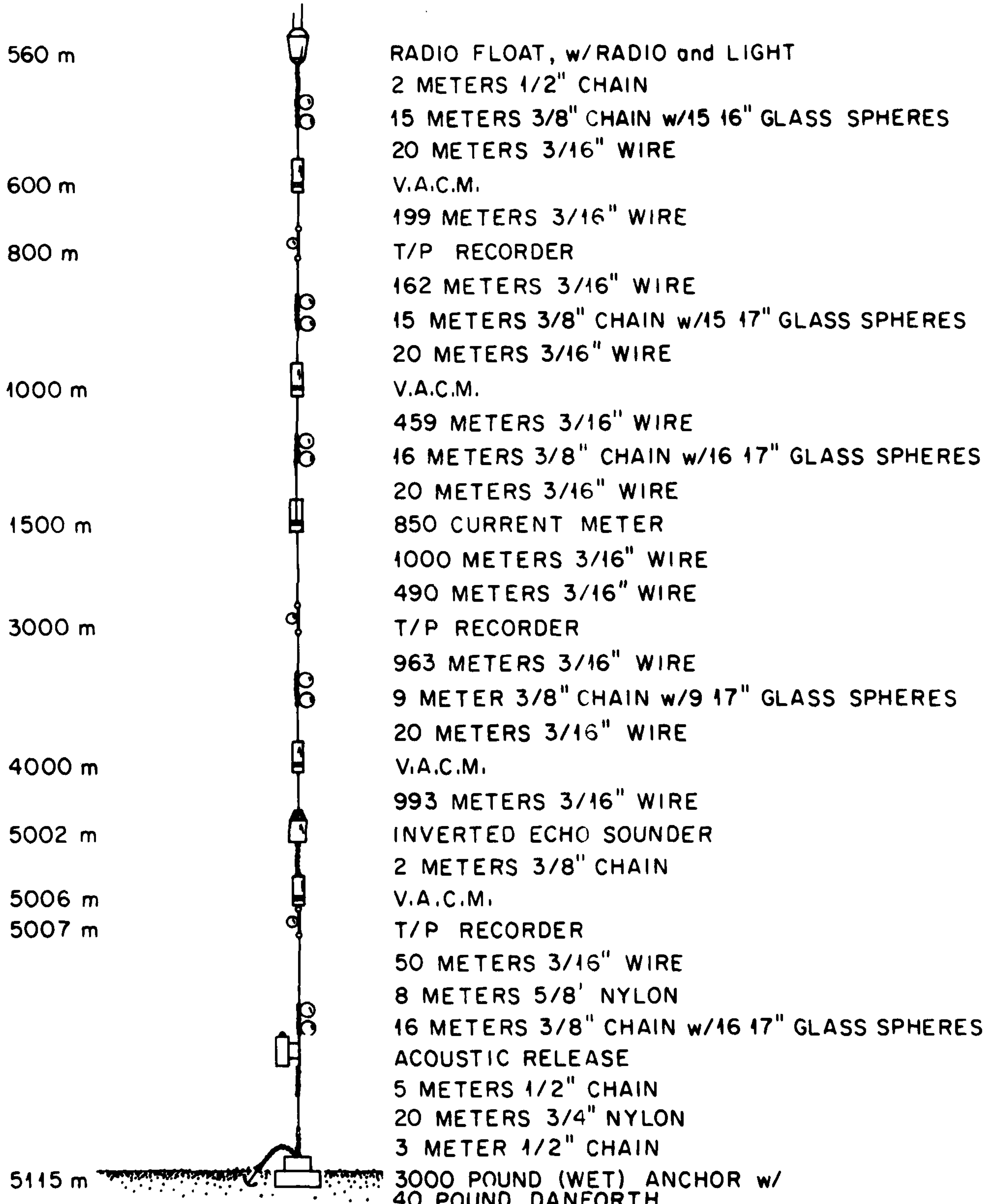

Figure 1

TYPICAL POLYMODE MOORING CONSTRUCTION
(MOORED STATION #609)

POLYMODE DESIGN CURRENT PROFILE

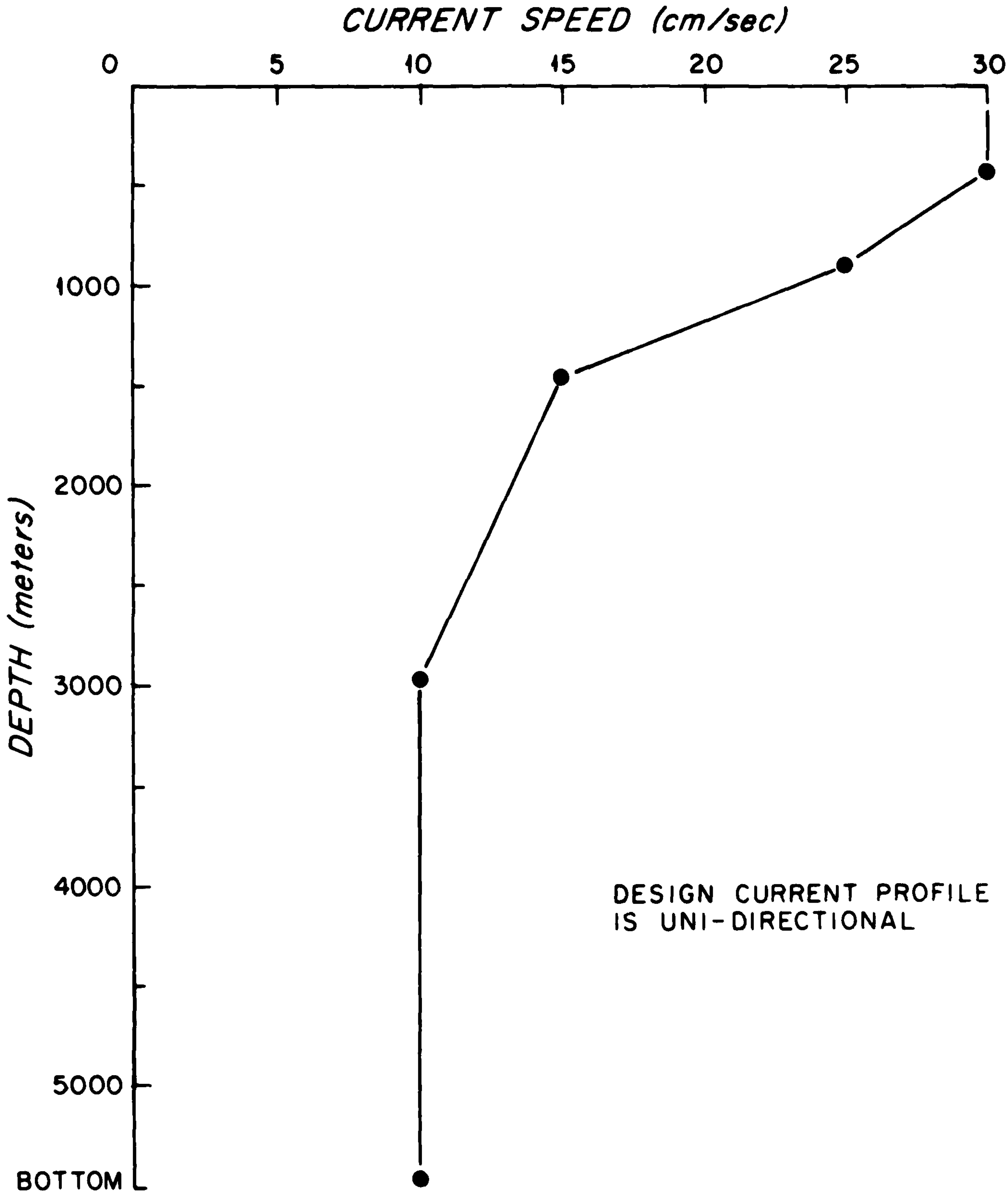

Figure 2

slide under the influence of a given current profile. Clearly with an anchor weight of 3,000 pounds, a vertical line force of 2,000 pounds and a drag force of 200 pounds the anchor should not move with the standard design current profile applied. However, two moorings from the first setting of Array II were found miles away from the launch site after a strong southerly meander of the Gulf Stream swept the area. It is now routine practice to attach an auxilliary Danforth anchor to each clump anchor as insurance against dragging. After this evolutionary step there were no repeat occurances of station movement in the POLYMODE program.

Appendices II and III present mooring statistics for the POLYMODE moorings and other nearby current meter moorings. Instrument design depths requested by the investigators are listed and the "as launched zero current depth". These later depths are calculated using NOYFB, the ocean depth at the site, the adjustable lengths determined at sea and a zero current (static) profile. The as-launched depths indicated how close the investigators requirements have been met in design, construction and deployment.

Nearly all instruments were placed within the accuracy limits of line-measuring equipment or ocean-bottom depth resolution provided by the depth recorders on the ships. Deployments and recovery techniques of all these moorings remained essentially unchanged throughout the program (Heinmiller, 1976).

POLYMODE Buoy Group Cruise Summaries

R/V CHAIN Cruise 116
July 22, 1974 to August 10, 1974
Woods Hole to Woods Hole
Chief Scientist: Robert Heinmiller

The major effort of CHAIN 116 was the deployment of the nine moorings of the POLYMODE Array I. Other work conducted along with this effort included the final field work of the MODE program.

After departure from Woods Hole, Station 541, an engineering test mooring near Site D, was recovered. About 100 miles south, Station 536, a mooring of James Luyten's Gulf Stream array, was acoustically checked after reports that the release was transponding and not disabled. Further south a twenty-five hour CTD series was completed near the Mode West site mooring (Station 538) which was subsequently recovered. This was the first Buoy Group all-wire mooring and an inspection was conducted before deploying the Array I moorings which were designed in the all-wire configuration.

The first POLYMODE mooring, Station 542, was then set and a second twenty-five hour CTD series completed. The ship proceeded east along 28° N. recovering the Mode East site mooring, Station 540. XBTs were launched and echo-sounding records kept along the ship's track to the east. Mooring deployments were routine except for locating flat areas near the desired positions. CTD stations were taken at mooring sites. Two magnetometers were deployed along 28° N. for Richard P. Von Herzen. After the deployment of the triad of moorings near 55° W. the ship turned northwest to set a third magnetometer and make a CTD cast before reaching the site of Station 548, mooring VII of Array I. On the way north bottom surveying was conducted for the remaining sites, the moorings were deployed and CTDs taken at and between mooring stations. Shipboard analysis of XBT data indicated the presence of either a cold core ring or Gulf Stream meander in the area of 39° N., 65° W., where a CTD station was taken before heading back to Woods Hole.

The ship's track is shown in Figure 3.

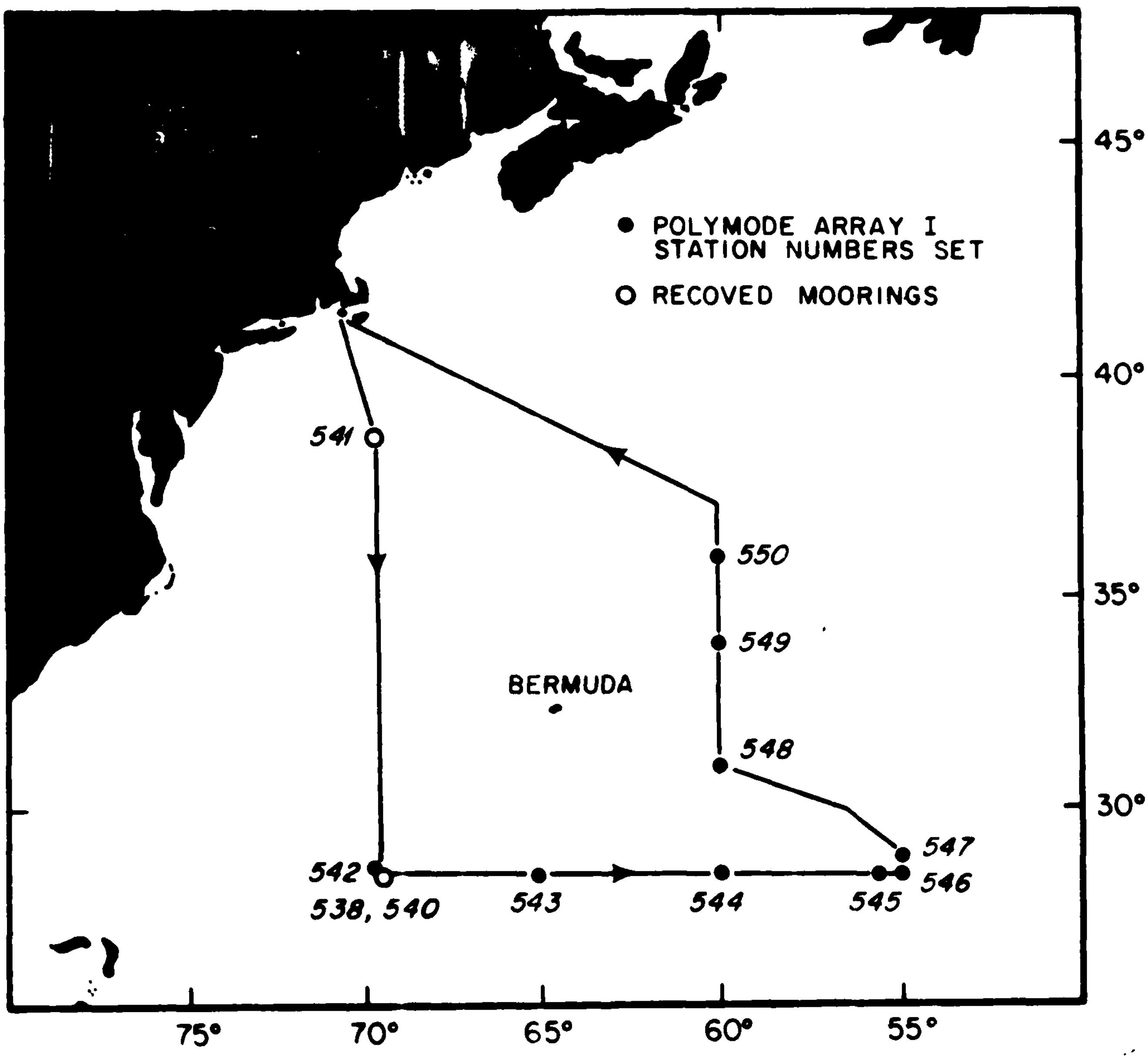

Figure 3: Cruise Track R/V CHAIN-116; July 22 to August 10, 1974.

R/V KNORR Cruise 49
April 21, 1975 to May 19, 1975
Woods Hole to Woods Hole
Chief Scientist: George Tupper

Approximately nine months after they were deployed the POLYMODE Array I moorings were recovered and the Array II moorings set. South of Woods Hole the first order of business was the recovery of a Vector Averaging Current Meter (VACM) engineering test mooring, Station 551. An XBT watch had been maintained across the Gulf Stream and was continued throughout the POLYMODE work areas. As the ship continued south the westernmost Array I mooring (Station 542) was recovered. The track north after recovery of Station 543 took the ship to the vicinity of Bermuda for the deployment of a three-mooring triangle Microstructure array around Bermuda for Nelson Hogg, a true "Bermuda Triangle". The lights of Bermuda lit up the horizon as the KNORR passed by without a stop. Station 556 was then deployed for a short-term test of a deep-water circulator system developed by Susumo Honjo of the WHOI Chemistry Department. It was to be recovered later on this cruise.

Getting back to POLYMODE work Station 549 (Array I, mooring VIII) was recovered. Further north acoustic contact was not established with Station 550. A search was conducted but the mooring failed to surface. The east-west axis of Array II (36° N.) was surveyed for topographic features and William J. Schmitz, the principal Array II scientist on board, decided to move the north-south axis to 55° W. instead of 57° W. as originally planned. The central mooring (Station 557) was set, followed by the two easterly moorings. The ship then headed directly to Site 12, the northernmost Array II mooring position, deployed Station 560 and subsequently headed south setting the axis moorings one right after the other. Finally, after Station 566 was set at Site 5, the glass-ball flotation supply was exhausted and the remainder of the Array I moorings had to be recovered in order to complete the Array II work.

Station 548 to the southwest was recovered. Conditions similar to those at Station 550 were encountered at 544 - no acoustic contact and no visual sightings or radio signals after release commands. After a thorough search 544 was reluctantly considered lost. It was later suspected that a faulty transistor in the release may have caused the batteries to deplete preventing recovery of both 550 and

544. Loran C navigation was not sufficiently accurate in these areas to track ship progress for a dragging operation. However, satellite fixes were sufficient for normal recovery work.

After the recovery of the eastern triad of Array I (Stations 545 to 547), flotation was prepared and the mooring at Site 7, Station 567, was deployed. Site 6 on the east-west array axis had previously been selected during the bottom survey along 36° N. The mooring there was deployed as Station 568. Returning to the site of the lost Station 550 a second search was conducted without success. The circulator mooring (Station 556) north of Bermuda was recovered without difficulty followed by a two-day run back to Woods Hole.

The ship's track is shown in Figure 4.

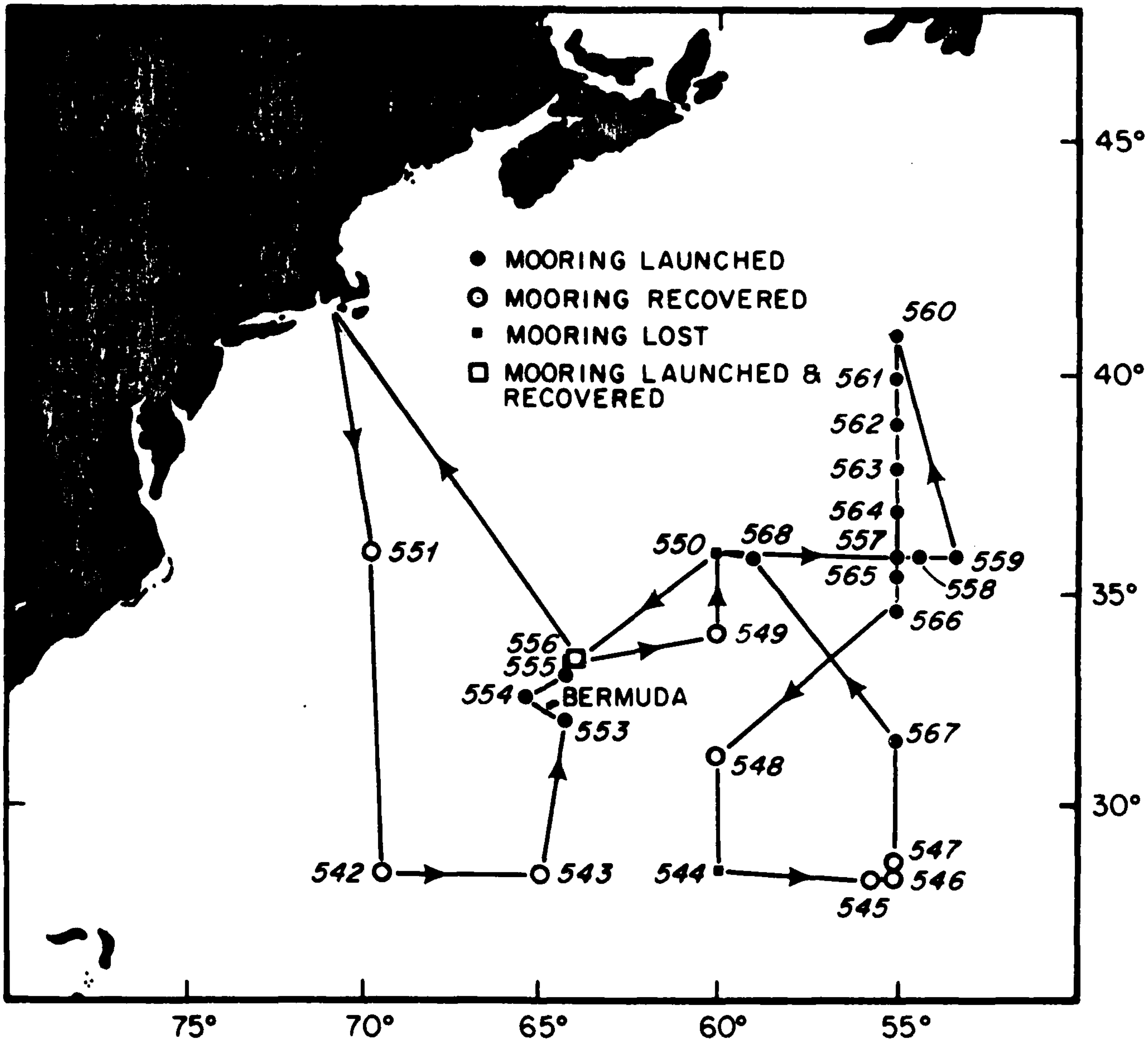

Figure 4 : Cruise Track R/V KNORR-49; April 21 to May 19, 1975.

R/V CHAIN Cruise 129
December 3, 1975 to December 23, 1975
Woods Hole to Woods Hole
Chief Scientist: Keith Bradley

The most repeated phrase of CHAIN 129 was "more rough weather". As the ship headed almost due east from Woods Hole rough seas were encountered at the northernmost site of Array II, Site 12, Station 560. On station for nearly eight months this mooring was recovered and a new identical mooring set in its place and a CTD station taken. This routine of recovery, setting and CTDs was repeated at all the Array II sites. Stations 562 and 563 had experimental armored Kevlar mooring line and flotation above the instruments. This line was recovered, inspected and later redeployed as part of a continued long-term test.

Continuing south along 55° W. the CHAIN reached the east-west axis of the array (36° N.) as the bottom fell out of the barometer. Rather than wait for the weather to clear the ship headed (was blown!) south to the southernmost site, #7. During the wait for better seas for mooring recovery the replacement, Station 580, was set five miles east of 567 which was recovered about twelve hours later.

The ship then headed north servicing Site 5, Site 3 and the central mooring Site 1. The final site, 6, to the west was recovered, reset as Station 584, and a CTD cast completed. All the Array II moorings of the first setting were in position as launched and the replacement moorings were set usually within a mile of the previous moorings.

Due to the time expended waiting for better weather or changing planned ship tracks the revised time schedule did not allow a transit to Bermuda to recover the Microstructure array set on KNORR Cruise 49. Arrangements were later made to recover these from the USCGC EVERGREEN. On the return passage to Woods Hole after the Array II work, two engineering moorings were set on the Continental Slope south of Woods Hole. One was a high-tension test of the previously deployed Kevlar samples; the other was a hybrid-wire/Kevlar test with a large sphere for upper flotation promising better mooring performance in high-current regions.

This cruise marked the final scientific cruise for the CHAIN. Her science credentials include an around-the-world voyage and over 600,000 miles of research cruises.

The ship's track is shown in Figure 5.

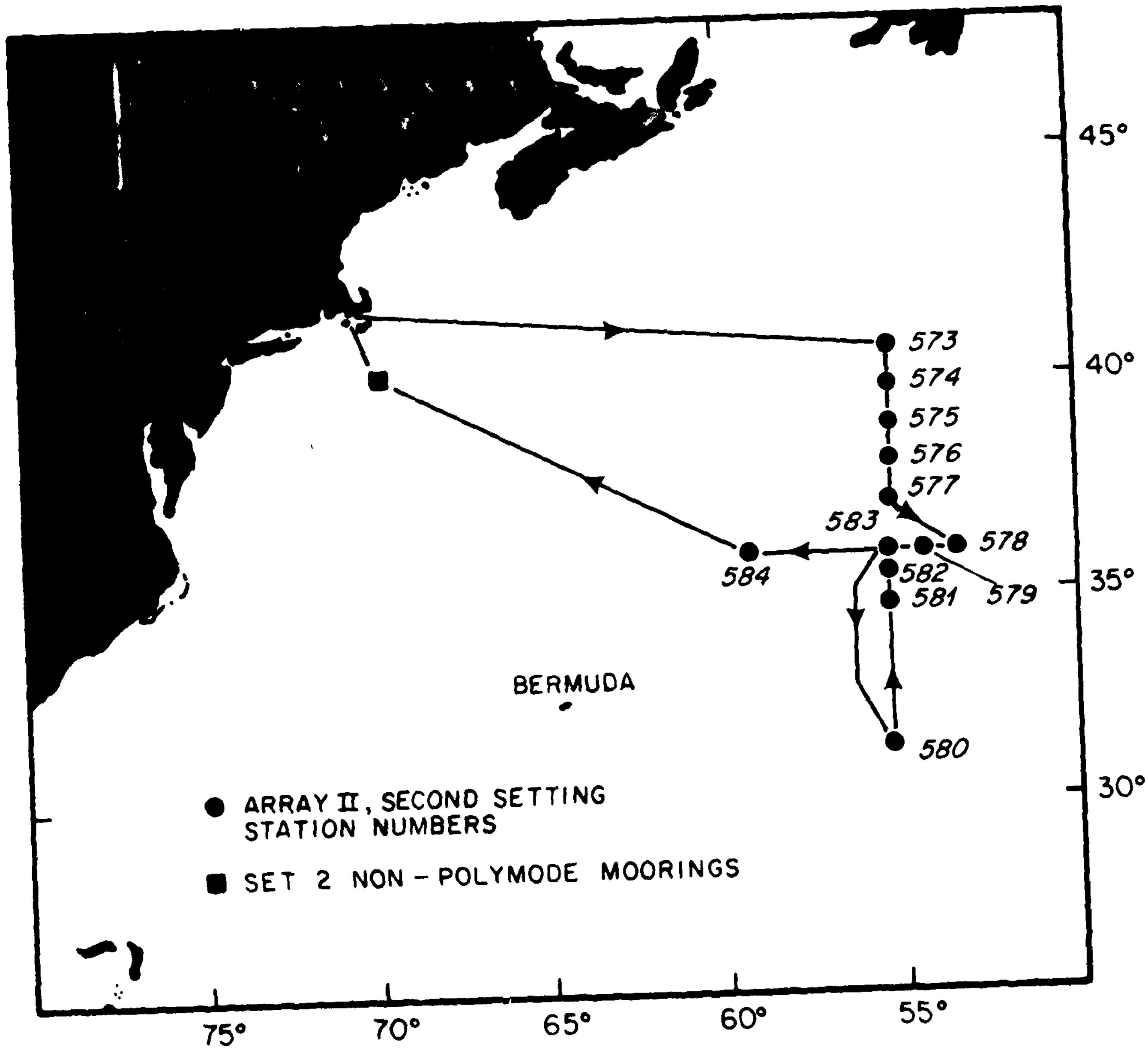

Figure 5: Cruise Track R/V CHAIN-129; December 3 to December 23, 1975.

R/V KNORR Cruise 60
September 29, 1976 to October 28, 1976
Woods Hole to Woods Hole
Chief Scientist: Keith Bradley

The mooring effort of the Array II program was expanded during the third setting of that array. Additional scientific information from the analysis of data from Array I and the first setting of Array II plus the availability of more instrumentation provided the impetus to add three moorings to the final setting of Array II.

A southeasterly track from Woods Hole provided a direct crossing of the Gulf Stream; an XBT section was taken across the stream. Once across the KNORR set a course to Array II, Site 6 for its recovery, redeployment as Station 598 and a CTD station. To the east a new mooring was launched at Site 15 and a CTD station made. The central mooring, Station 583, was passed by and Sites 2 and 4 serviced (see comment below). Returning to Longitude 54° W. an XBT section was conducted while steaming north, to be compared later with a planned section down 55° W.

The mooring work south along 55° W. was routine, with recoveries, settings and CTDs. Stations 579 (Site 2) and 582 (Site 3) were not in the positions launched but had dragged their anchors in a general west southwest direction (about eight miles for 579 and three miles for 582). Thorough acoustic search patterns were employed to locate them. Subsequent review of all second setting current-meter records showed that a long meander of the Gulf Stream had passed through the array north of 35° N. Latitude. Pressure records from these moorings indicated that in some cases the tops of moorings had dipped 600 m lower as the meander passed through. Besides the CTD lowerings at each mooring site an extensive classical hydrographic section was conducted between 41° 50' N. and 30° 30' N. along 55° W. The hydrocasts were generally done between CTD stations and consisted of both deep and shallow casts; XBTs filled in the section.

Two moorings were launched just south of Array II, Site 7, one a non-instrumented engineering test of various constructions of Kevlar mooring line and the other the largest single anchor mooring yet designed by the Buoy Group. Comprising four large (1.8 m x 1.8 m x 3 m) sediment-trap frames, three circulator pumps and 125 flotation spheres, the mooring, called "PARFLUX", was set for Susumo Honjo as a pilot experiment. Deployment was well planned and exciting, taking about five hours.

Before returning to Woods Hole Valentine Worthington conducted an XBT survey to locate cold core rings west of the array. Although none were identified a pinched sock-like meander of the Gulf Stream was discovered and it was suspected that it might break off into a ring. Hydrostations were cast both inside and out of the feature and a satellite-tracked drogue buoy of Philip Richardson's was placed in the center of the loop. A direct track back to Woods Hole with XBTs all the way except for a short break due to high seas brought the KNORR home after thirty days at sea.

The ship's track is shown in Figure 6.

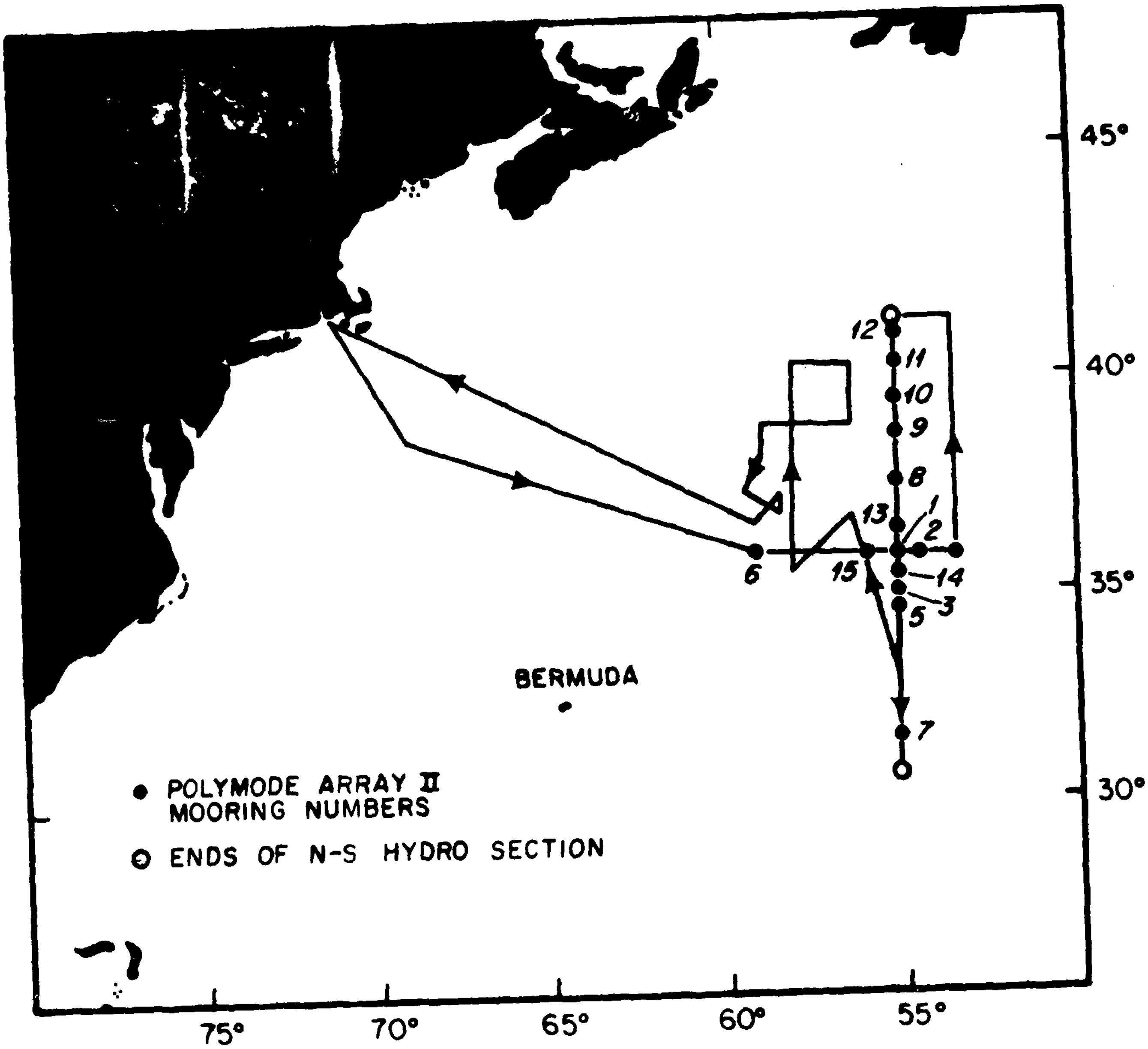

Figure 6: Cruise Track R/V KNORR-60;
September 29 to October 28, 1976.

R/V KNORR Cruise 66

Leg I: May 10, 1977 to May 22, 1977
Woods Hole to Bermuda
Chief Scientist: Keith Bradley

Leg II: May 26, 1977 to June 24, 1977
Bermuda to Bermuda
Chief Scientist: George Tupper

Leg III: June 28, 1977 to July 13, 1977
Bermuda to Woods Hole
Chief Scientist: Keith Bradley

A list of statistics will illustrate the magnitude of this cruise, the largest Buoy Group effort to date. About two-thirds of the total effort was POLYMODE related. Some of the more notable items include: a) a sixty-five day cruise, b) 8,000 miles of steaming, c) seventeen moorings and an acoustic beacon set and seventeen moorings recovered, d) 113 current meters and fifty-four other scientific instruments set or recovered from moorings, e) 506 XBTs, f) eighty-two CTD stations, g) twenty-four hydrostation casts, h) six satellite buoys launched, i) over 2,000 water samples analyzed, and j) forty-four participants as science-party members.

The first leg of the cruise was not POLYMODE work but the moorings set could be of interest to POLYMODE investigators (see Appendix III). After leaving Woods Hole the ship skirted the eastern seaboard remaining west of the Gulf Stream until reaching Diamond Shoals near Cape Hatteras and changing course to quickly cross the Gulf Stream. An XBT section was conducted going across.

Five moorings for Peter Rhines' Western Boundary Undercurrent Experiment were first deployed near the Blake-Bahama Outer Ridge. As with most mooring work on this cruise CTDs were taken at the mooring sites. Two near-bottom moorings were next placed to the southeast on the Hatteras Abyssal Plain along with an acoustic beacon for Laurance Armi's Benthic Boundary Layer Experiment. The beacon was necessary so that an acoustically tracked CTD could be "flown" very close to the heavily instrumented mooring. After an extensive near-bottom CTD survey the KNORR steamed to Bermuda for a partial change of the science party.

The second leg was devoted primarily to Array III work. Sufficient glass-ball flotation was not available for all ten moorings of Array III so Array II Sites 6, 15, 2 and 4, all along the east-west axis (36° N.), were recovered after departing Bermuda. Once again, CTDs were taken at the mooring sites and XBTs were dropped routinely

during the cruise. A long transit to the Mid-Atlantic Ridge area, during which a drogued satellite tracked drift buoy for Philip Richardson was launched at 36° 49' N., 46° 27' W., was followed by an extensive CTD survey for Terrance Joyce's Mediterranean Water Front Experiment. Neutrally buoyant vertical current meters were deployed, tracked and recovered during the CTD work, along with the launch of a second satellite buoy.

The eastern POLYMODE Array III Cluster B of five moorings was then launched over a very rough bottom. A towfish mounted transducer allowed a top-speed bottom survey. Carl Wunsch of MIT changed the original cross-shaped Cluster B array into a somewhat slanted "T". Cluster A on the west side of the ridge was deployed in a rough cross shape again due to the rough bottom and a desire to have instrument depth as designed.

With the Array III clusters deployed the ship headed to Bermuda taking XBTs every two hours. The southernmost Array II Site 7 mooring was recovered along with two other moorings on station nearby. One was an engineering Kevlar test moor set on KNORR 60 and the other a heavily instrumented internal wave self-interaction mooring for Melbourne Briscoe set on KNORR 63. A diamond-shaped pattern of CTD stations was taken around this site, the data being valuable to both POLYMODE and Internal Wave investigators. The ship then returned to Bermuda.

The final leg of KNORR 66 headed nearly due east to begin a hydrographic section for Valentine Worthington from 32° 25' N. northward along 55° W. as the north-south axis moorings of Array II were being recovered. As on KNORR 60 the classical type of hydrographic stations were interspersed with CTDs at the recovered mooring sites. The CTD package in use included a newly developed nephalometer and a large twenty-four bottle rosette water sampler. Mooring recovery work was routine. With a little extra time available due to good weather KNORR headed southwest deploying four satellite-tracked drogue buoys across the Gulf Stream. On the return to Woods Hole two hydrographic stations were cast on either side of the Gulf Stream.

The ship's track for the two POLYMODE legs of the cruise is shown in Figure 7.

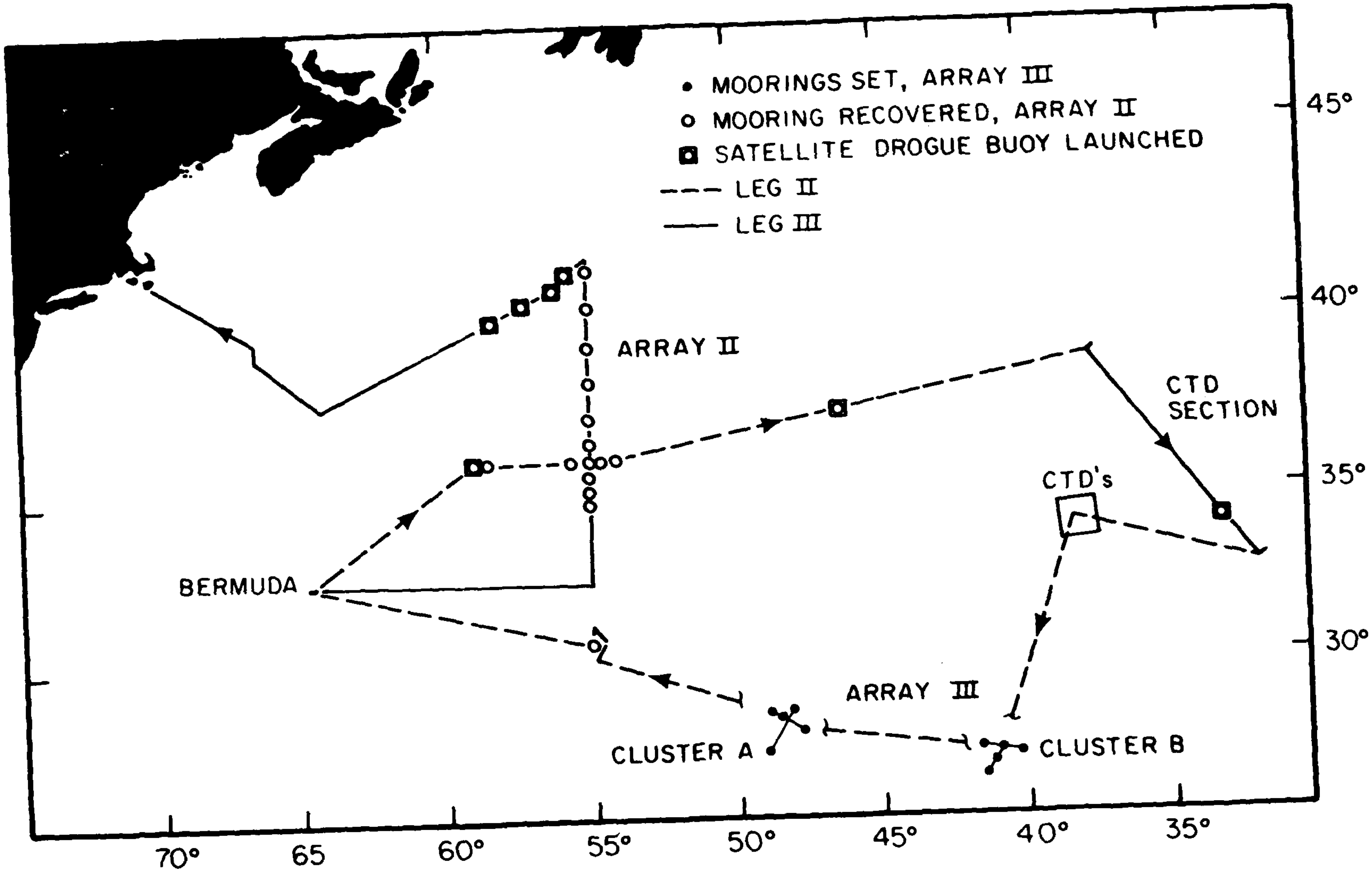

Figure 7: Cruise Track R/V KNORR-66, Legs II & III; May 26, to July 13, 1977.

R/V ATLANTIS II Cruise 100

Leg I: April 21, 1978 to May 12, 1978
Woods Hole to Bermuda
Chief Scientist: Keith Bradley

Leg II: May 16, 1978 to June 4, 1978
Bermuda to Woods Hole
Chief Scientist: George Tupper

POLYMODE activities again dominated the major portion of the work on this research cruise. A series of fourteen CTD stations along 70° W. for Gerald Needell began shortly after departure. The series started on the Continental Shelf and went due south to 34° N. The site for the best location of the POLYMODE Local Dynamics Experiment (LDE) moorings was not final before sailing. An XBT survey was carried out from 68° 30' W. to 67° W. and from 31° 30' to 30° N. taking two days and about fifty XBTs. The results were transmitted via satellite to New York where many of the POLYMODE investigators were meeting. The ten-mooring LDE array was then centered at 31° N., 69° 30' W. Scientists anticipated that at that position features noted in the survey would pass through the array in June when an intense multi-ship research effort would take place in the area.

The five northern moorings were launched without mishap and a CTD cast made at the array center. With the mooring crew exhausted the AII steamed west to recover Peter Rhines' Western Boundary Undercurrent moorings (WBUC). CTD stations were to be taken between the LDE and WBUC. At the second CTD site (#17) catastrophe struck. The large CTD package with twenty-four bottle rosette sampler, bottom pinger and nephalometer was lost when the electro-mechanical CTD cable parted. A subsequent deep-water dragging operation failed to snag the unit or the nest of wire on the bottom. To compound the injury although four WBUC moorings were recovered, a fifth, previously reported not to be answering acoustic commands, was not found. A large acoustic search pattern was executed to the southeast along a topographic spur. It was believed that an extremely strong current flow entered the area and dragged the mooring in that direction down the slope of the spur.

With time running low and neither the search for Station 619 nor the dragging for the CTD package successful the ship had to return to the LDE area to deploy the final five moorings. This was done routinely in about twenty-eight continuous hours of work. Exhausted again it was time to head for Bermuda.

With a new science party the ship headed southeast to recover the POLYMODE Cluster A and B moorings. Along the way a free-drifting satellite buoy was recovered, its position reported via radio from Woods Hole. Once in the general recovery area a shipboard radio direction finder guided the ship alongside the drifter. The cluster array recoveries were routine. CTDs were taken at each site. One station (630) contained a time capsule which had been at 4,500 meters depth for nearly a year. It contained memorabilia from the KNORR 66 setting cruise such as a cup of chowder, a tape recording of songs by the "KNORR 4 & 2", etc. Its retrieval boosted the spirits of weary sailors.

At each cluster center a single site mooring was deployed to be recovered in October of 1979. On the return to Woods Hole a message was received that a second satellite buoy was now near Bermuda. A similar search was successful and this time a buoy was recovered that had been adrift for fourteen months. When the ship was crossing the Gulf Stream on the way home an engineering mooring was placed in the Stream core to evaluate the performance of this so-called "floppy" mooring design with high mooring tension from the bottom to the 1,200 meter depth and then a low-tension or "floppy" section above to 475 meters.

The ship's track for Leg I is shown in Figure 8 and for Leg II in Figure 9.

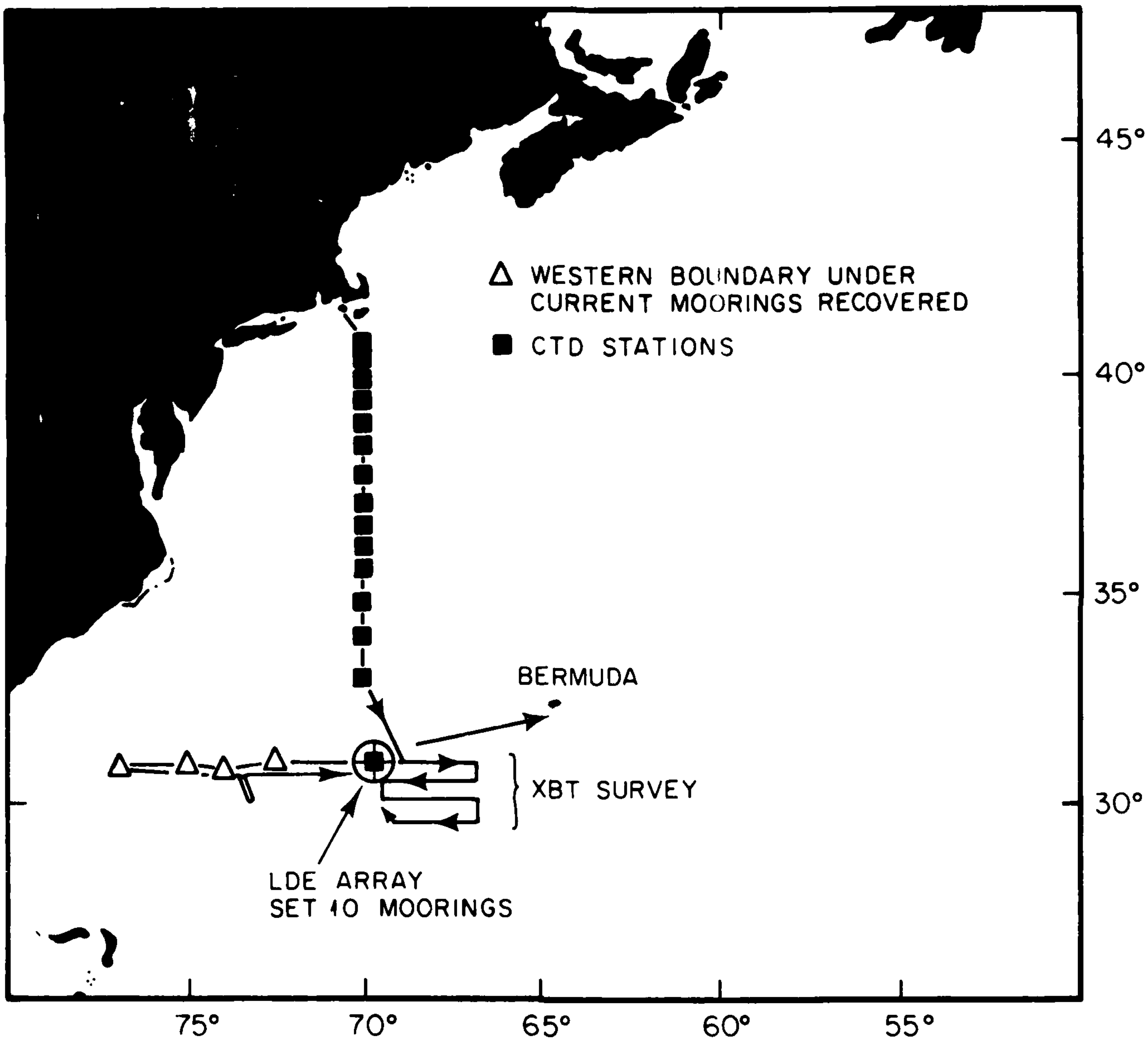

Figure 8: Cruise Track R/V ATLANTIS II -100, Leg I; April 21 to May 12, 1978.

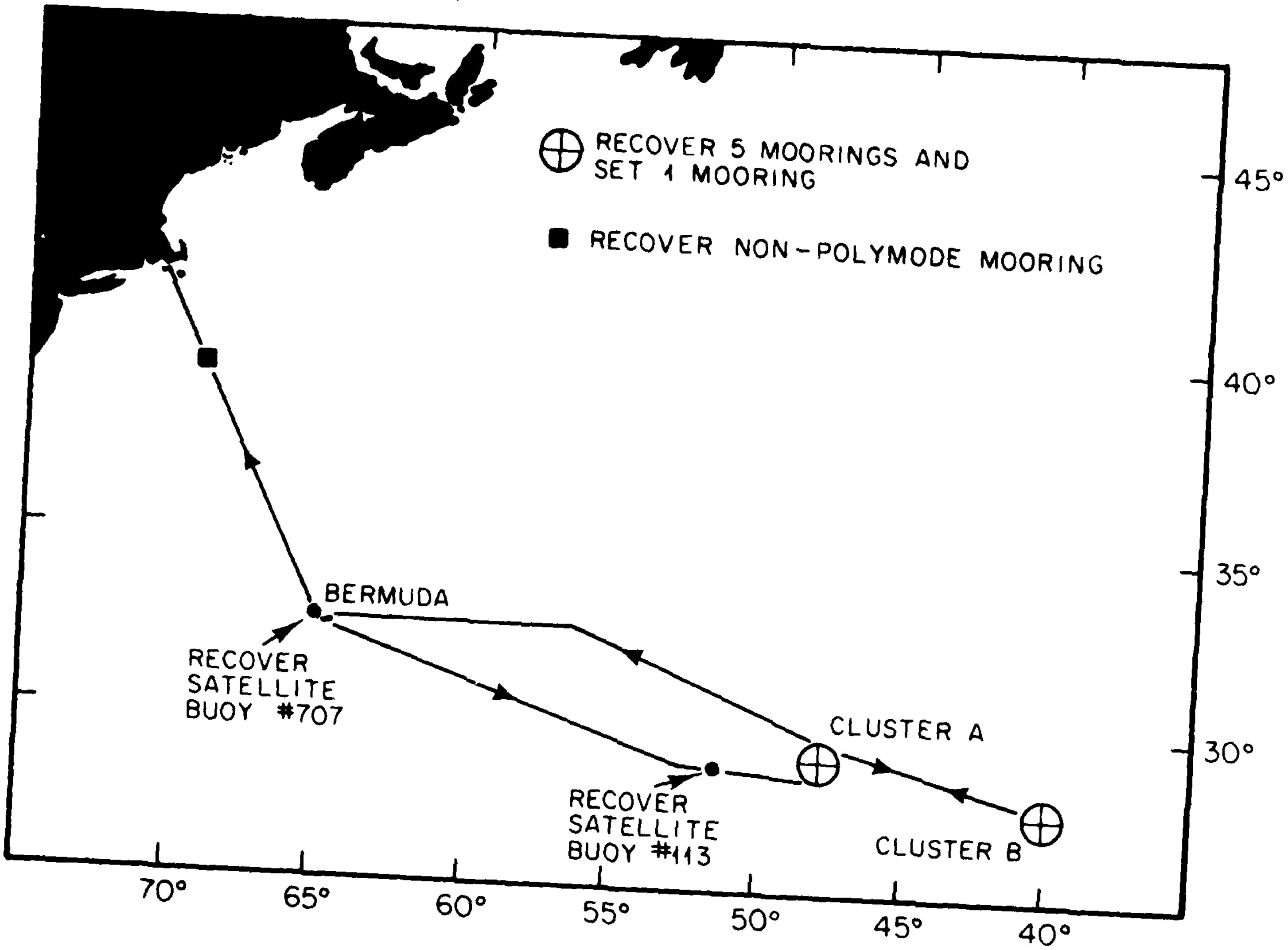

Figure 9: Cruise Track ATLANTIS II-100, Leg II, May 16 to June 4, 1978.

R/V OCEANUS Cruise 66
July 17, 1979 to August 3, 1979
Woods Hole to Woods Hole to Woods Hole
Chief Scientist: George Tupper

The recovery cruise of the ten Local Dynamics Experiment (LDE) moorings was originally scheduled for May on the R/V ATLANTIS II. Delays in her conversion from steam to diesel power caused a rescheduling of the cruise dates and a change in ships. Due to the smaller size of the OCEANUS all ten moorings could not be recovered on one leg so the OCEANUS was to go out, recover five or six moorings, conduct a three-day CTD survey, return to Woods Hole to off-load gear and then immediately return for the remaining work. That was the plan.

After a fast transit to the work area with XBTs taken across the Gulf Stream difficulties began with the CTD equipment. Only a few stations were completed before major repairs were needed necessitating a return to Woods Hole. It was decided to recover as many moorings as possible crowding every bit of space on the ship with mooring gear. There was no acoustic contact with Station 640, LDE Mooring 10, which was next to the central mooring. All other recoveries were routine. Upon return to Woods Hole the nine moorings were off-loaded, the CTD repaired and the ship departed late the next day. In port equipment was loaded for a dragging operation for Station 640. It was believed that either the mooring was on station or the release had fired for some reason and it was no longer there. Two days of dragging under conditions of good weather, navigation and equipment failed to snag the mooring. The mooring probably was no longer there. CTD stations were continued and a total of eleven stations were completed at all sites except LDE #8.

Before returning to Woods Hole an engineering test mooring was launched in deep water north of the Gulf Stream. It was a long-term acoustic release test of equipment supplied by WHOI, EG&G Sea-Link, Benthos and Ocean Research Equipment; representatives of each firm participated in the launch. Recovery was scheduled for spring of 1980.

The ship's track is shown in Figure 10.

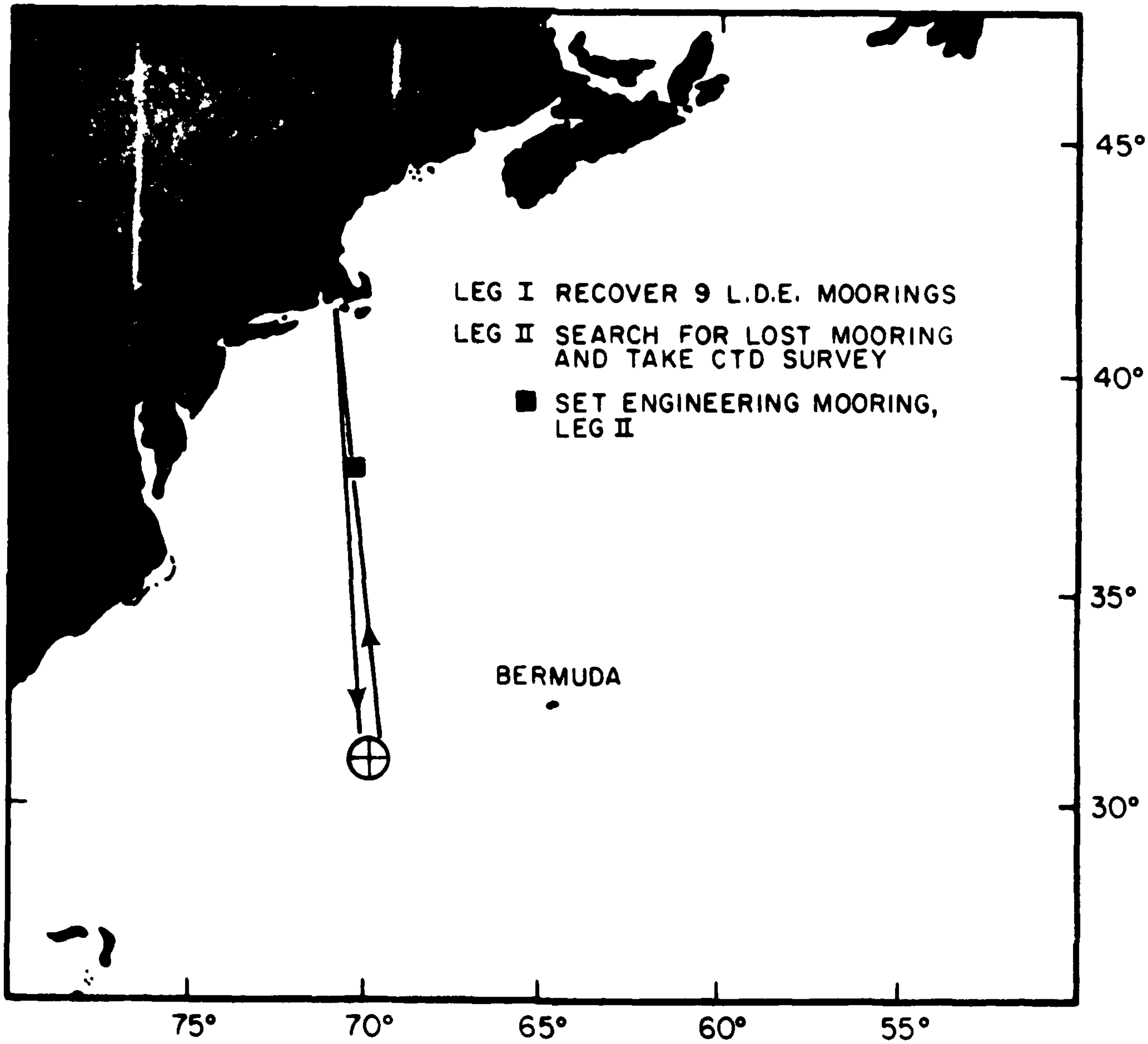

Figure 10: Cruise Track R/V OCEANUS-66; July 17 to August 3, 1979.

R/V KNORR Cruise 75
October 12, 1979 to November 7, 1979
Woods Hole to Woods Hole
Chief Scientist: George Tupper

The final field exercise of the POLYMODE program was the recovery of the site moorings at Clusters A and B of Array III. When KNORR 75 left Woods Hole it made a direct track to these sites routinely recovering the moorings and taking a CTD station at each cluster. XBTs were dropped throughout the cruise at ten or twenty mile spacings. Station 549, the site mooring at Cluster B, set a Buoy Group record for total time on station of 515 days with Station 548 close behind at 513 days. Neither of these moorings exhibited any more deterioration than is usually found on moorings deployed for a year. Battery life and tape storage capacity set a practical upper limit of about eighteen months of on-station time. A very large amount of XBT wire was wrapped on the mooring cable of Station 548 near the 700 meter depth but luckily did not foul the current meter.

The major effort of the cruise now began with the ship steaming to the northwest to set eight moorings for the joint Gulf Stream Extension/Norwegian Sea Overflow Intrusion Experiment. Although not part of the POLYMODE program the moorings may later be of interest to POLYMODE investigators; the mooring details are listed in Appendix III. Extensive CTD surveying was conducted so that Nick Fofonoff and Laurence Armi could best position the moorings to match hydrographic features. Three of these moorings supported Vector Averaging Current Meters that had been modified to record temperatures from sensors spaced ten to twenty meters from the instruments in addition to current speeds and directions.

An interesting sidelight of the cruise was provided by scientists and technicians from NASA, NORDA and the Navy Fleet Meteorological Service. Their function was to provide ground-truth data for interpreting satellite images. During the cruise they launched meteorological balloons and flew large instrumented kites while at the same time monitoring weather satellite transmissions through special antennas mounted on the KNORR. After the completion of the mooring work a short track to the northwest provided them the opportunity to observe a specific

weather front. Then a due-west course to Woods hole completed the Buoy Operations Group's participation in POLYMODE.

The ship's track is shown in Figure 11.

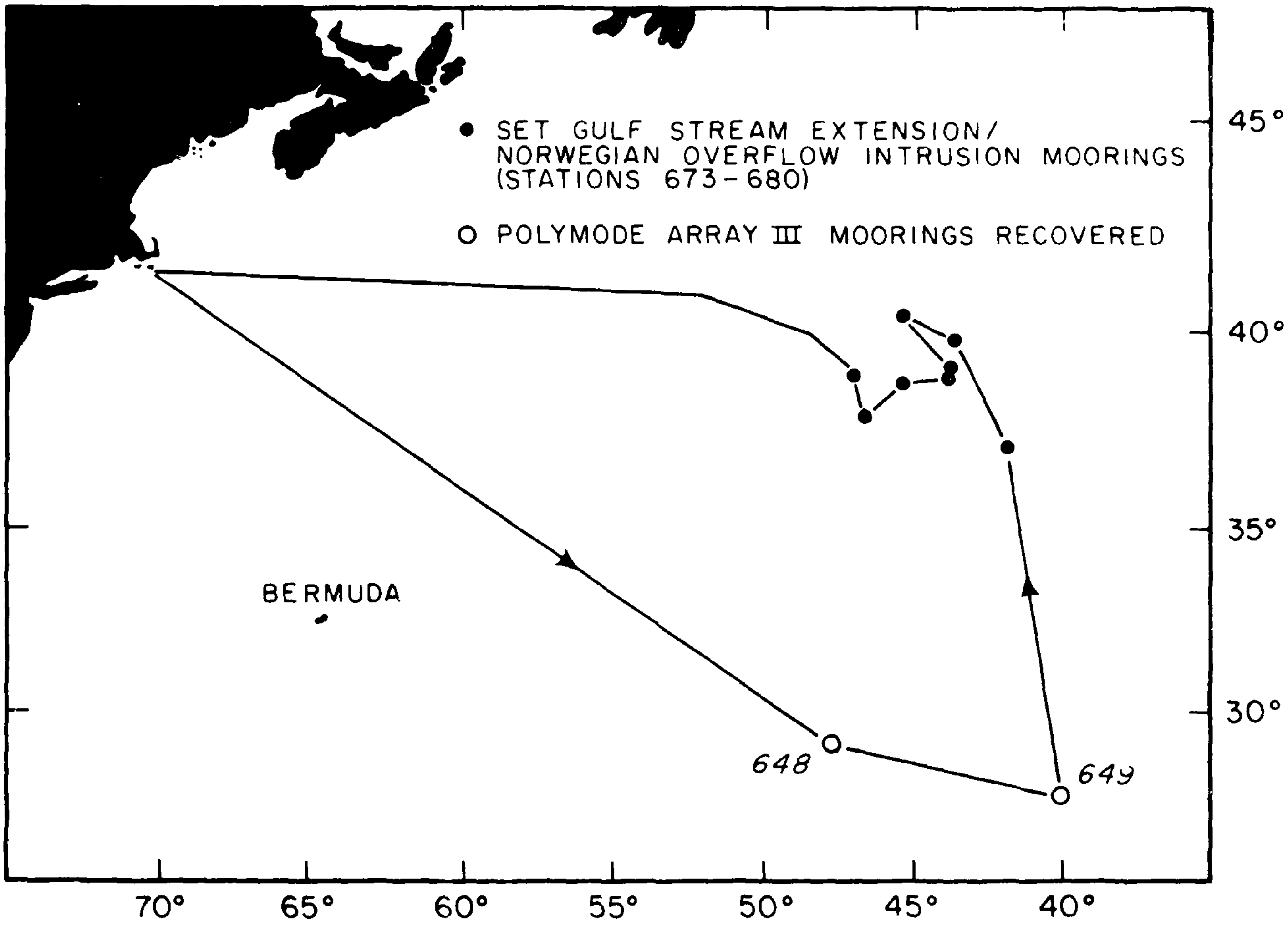

Figure 11: Cruise Track R/V KNORR-75;
October 12 to November 7, 1979.

ACKNOWLEDGMENTS

The scientists, engineers, technicians and data processors have all contributed to the success of this multi-year international experiment. The ships' officers and crew of the R/V ATLANTIS II, R/V CHAIN, R/V KNORR and R/V OCEANUS should be praised for their fine work during 240 days of at-sea field work. Special mention should be made of the Woods Hole Buoy Group Operations Section's preparation of instruments, moorings and acoustic releases and their precise deployment and successful recovery. Over 200 miles of mooring cable, 100 tons of anchors and 350 scientific instruments were successfully launched and recovered mainly through their efforts.

These investigations were supported by the Office of Naval Research under contracts N00014-66-C-0241, NR 083-004; N000-74-C-262, NR 083-004; N00014-76-C-0197, NR 083-400, and by the Office for the International Decade of Ocean Exploration of the National Science Foundation under grants GX-29054, OCE-75-03962 and OCE-77-19403. This report is POLYMODE Technical Report Number T-33.

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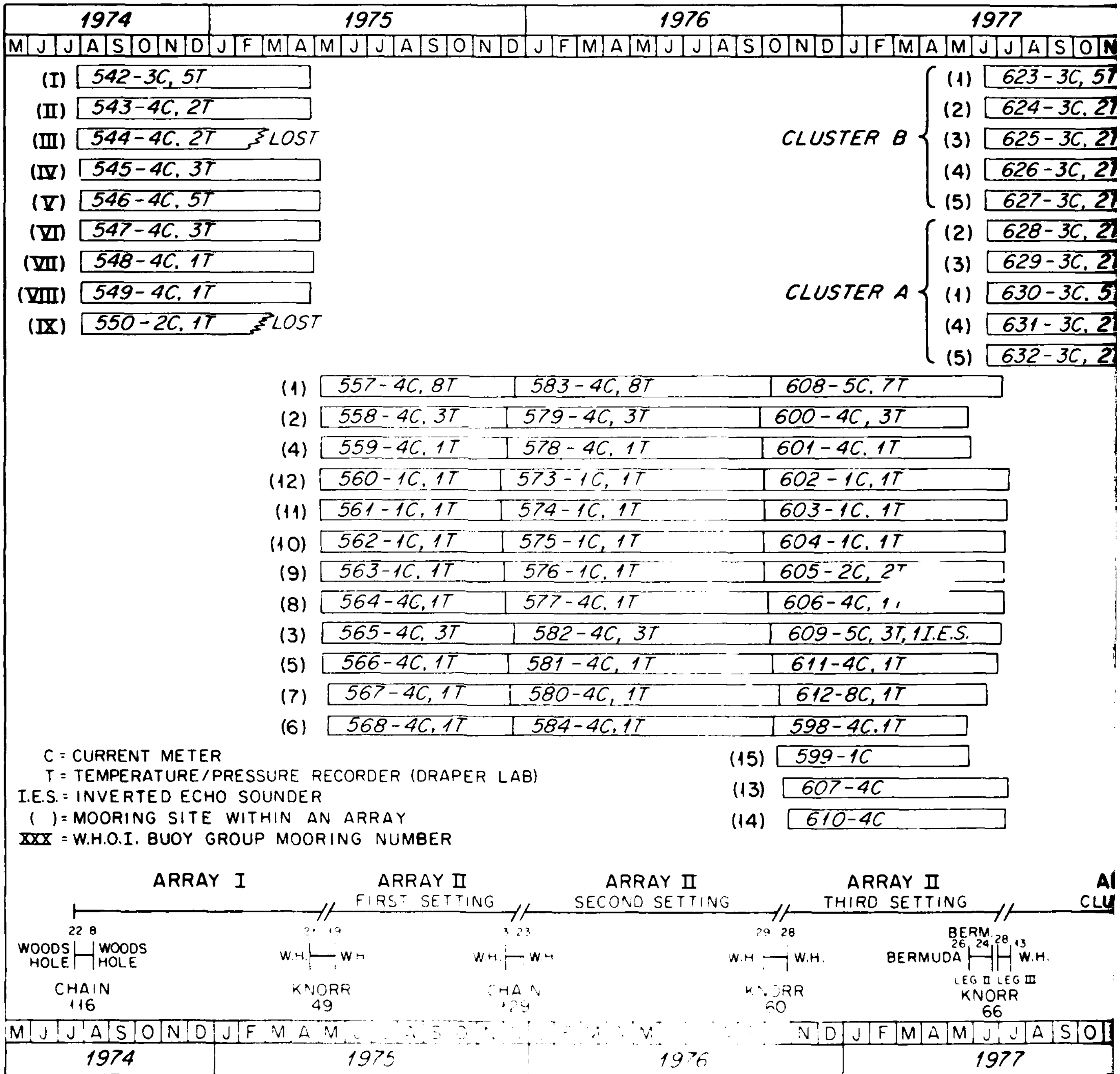
Appendix I

CHRONOLOGY OF POLYMODE MOORING OP
CONDUCTED BY W.H.O.I. BUOY GRO



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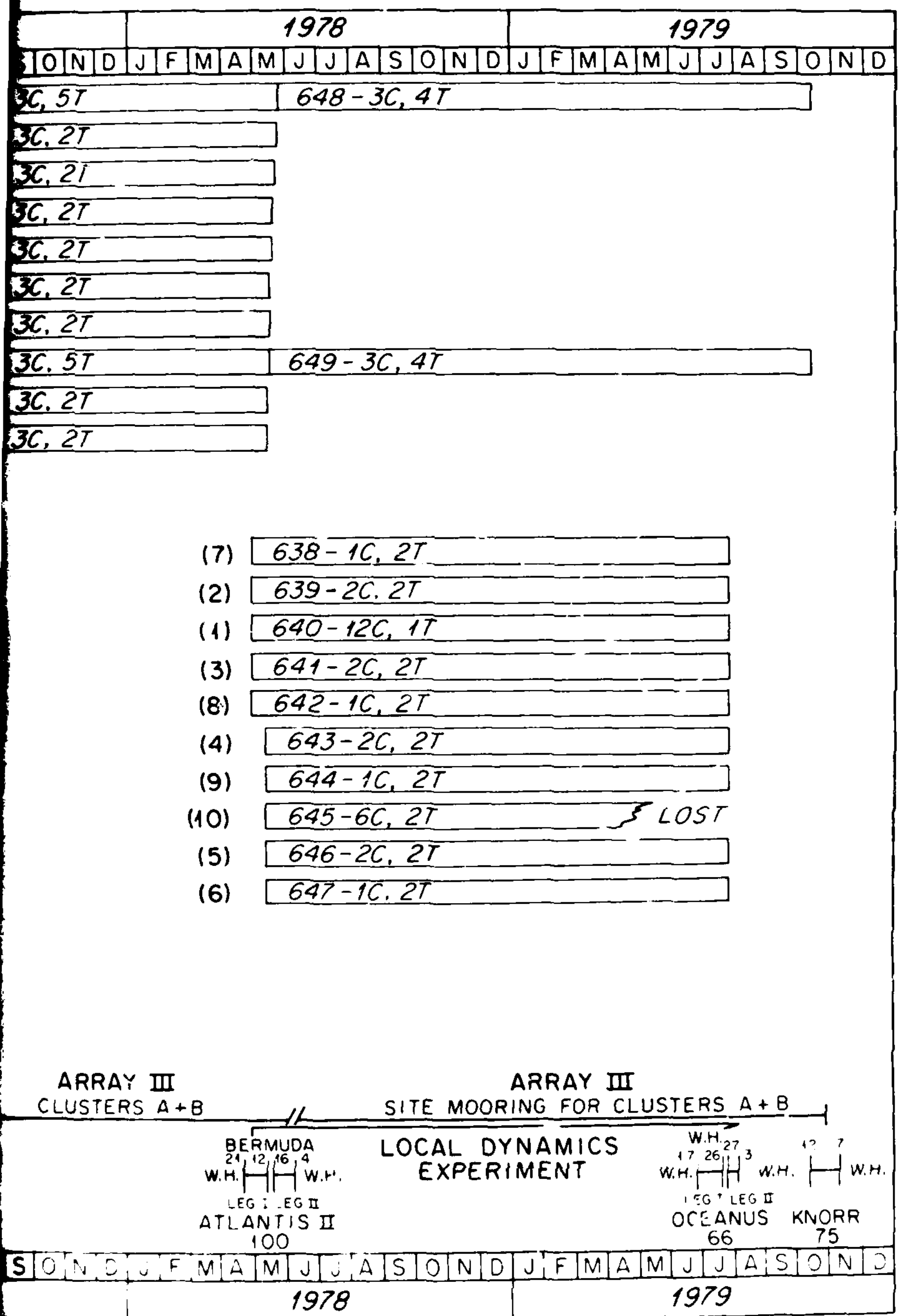

Appendix II

WHOI Mooring Operations Summary

POLYMODE Program

*

VACM = Vector Averaging Current Meter

850 = EG&G Current Meter

T/P = Temp./Press. Recorder (MIT)

Sta. #	Lat & Long	Dates Set and Rec	Days Dur.	Instr. Type	Instr. Design Depth (m)	As Launched Zero Current Depth (m)	Remarks
542	28° 01!4 N. 69° 39!0 W.	27-VII -74 26-IV -75	274	VACM	500	495	Mooring I of Array I
				T/P	800	796	
				T/P	1,000	996	
				850	1,500	1,499	
				T/P	2,000	1,999	
				T/P	3,500	3,499	
				850	4,000	4,000	
				T/P	4,003	4,003	
543	27° 57!6 N. 64° 57!8 W.	30-VII -74 27-IV -75	272	VACM	500	502	Mooring II of Array I; Milliman samples attached along mooring line
				T/P	800	802	
				VACM	1,000	1,002	
				VACM	2,000	2,002	
				850	4,000	4,003	
				T/P	4,003	4,006	
544	28° 00!0 N. 60° 05!8 W.	1-VIII-74 Lost	?	VACM	500	519	Mooring III of Array I; no acoustic contact during recovery, search pattern conducted
				T/P	800	819	
				VACM	1,000	1,019	
				VACM	2,000	2,019	
				850	4,000	4,021	
				T/P	4,003	4,024	

Summary, Continued

Sta. #	Lat & Long	Dates Set and Rec	Days Dur.	Instr. Type	Instr. Design Depth (m)	As Launched Zero Current Depth (m)	Remarks
545	27° 50!2 N. 55° 34!5 W.	2-VIII-74 12-V -75	284	VACM	500	496	Mooring IV of Array I; Milliman samples attached along mooring line
				T/P	800	796	
				VACM	1,000	996	
				VACM	2,000	1,996	
				T/P	2,003	1,999	
				850	4,000	4,004	
				T/P	4,003	4,007	
546	27° 54!3 N. 54° 54!6 W.	3-VIII-74 12-V -75	283	VACM	500	498	Mooring V of Array I
				T/P	800	798	
				VACM	1,000	998	
				T/P	1,400	1,398	
				VACM	2,000	1,998	
				T/P	3,000	3,004	
				850	4,000	4,011	
				T/P	4,003	4,014	
				T/P	5,000	5,006	
547	28° 12!6 N. 54° 56!6 W.	3-VIII-74 13-V -75	284	VACM	500	496	Mooring VI of Array I
				T/P	800	796	
				VACM	1,000	996	
				VACM	2,000	1,996	
				850	4,000	4,000	
				T/P	4,003	4,003	
				T/P	5,000	4,997	
548	31° 01!5 N. 60° 04!3 W.	5-VIII-74 10-V -75	279	VACM	500	500	Mooring VII of Array I; Milliman samples attached along mooring line
				T/P	800	800	
				VACM	1,000	1,000	
				Tens'meter	1,970	1,971	
				VACM	2,000	2,001	
				VACM	4,000	4,001	
				Tens'meter	5,450	5,450	

Summary, Continued

Sta. #	Lat & Long	Dates Set and Rec	Days Dur.	Instr. Type	Instr. Design Depth (m)	As Launched Zero Current Depth (m)	Remarks
549	33° 59!3 N.	6-VIII-74	269	VACM	500	502	Mooring VIII cf Array I
	60° 00!6 W.	1-V -75		T/P	800	802	
				VACM	1,000	1,002	
				850	2,000	2,002	
				VACM	4,000	4,002	
550	36° 02!6 N.	7-VIII-74	?	850	2,000	2,001	Mooring IX of Array I; no
	60° 02!4 W.	Lost		T/P	2,500	2,501	acoustic contact during recovery,
				VACM	4,000	4,003	search pattern conducted
557	35° 53!0 N.	3-V -75	230	VACM	600	600	Mooring #1 of Array II, first
	55° 03!8 W.	18-XII -75		T/P	800	799	setting
				VACM	1,000	1,000	
				T/P	1,200	1,200	
				VACM	1,500	1,499	
				T/P	2,000	2,000	
				T/P	2,500	2,501	
				T/P	3,000	3,001	
				T/P	3,500	3,500	
				VACM	4,000	4,001	
				T/P	4,500	4,501	
				T/P	5,000	5,001	
558	35° 56!8 N.	4-V -75	223	VACM	600	608	Mooring #2 of Array II, first set-
	54° 40!5 W.	12-XII -75		Incln'meter	800	807	ting, engineering instruments
				T/P	801	808	added
				850	1,000	1,008	
				850	1,500	1,506	
				Incln'meter	1,501	1,507	
				Incln'meter	3,000	3,007	
				T/P	3,001	3,008	
				VACM	4,000	4,007	
				Incln'meter	5,001	4,008	
				T/P	5,000	5,008	

Summary, Continued

Sta. #	Lat & Long	Dates Set and Rec	Days Dur.	Instr. Type	Instr. Design Depth (m)	As Launched Zero Current Depth (m)	Remarks
559	35° 58!2 N.	4-V -75	222	VACM	600	596	Mooring #4 of Array II, first
	53° 45!8 W.	11-XII -75		T/P	800	797	setting; VACM at 1,000 m was
				VACM	1,000	997	lost during recovery when cable
				850	1,500	1,497	fouled ship's propeller
				VACM	4,000	3,999	
560	41° 29!2 N.	6-V -75	215	T/P	4,000	3,992	Mooring #12 of Array II, first
	54° 59!8 W.	6-XII -75		850	4,002	3,994	setting
561	40° 28!0 N.	6-V -75	217	850	4,000	3,982	Mooring #11 of Array II, first
	55° 00!0 W.	8-XII -75		T/P	4,200	4,181	setting
562	39° 29!0 N.	7-V -75	216	850	4,000	4,000	Mooring #10 of Array II, first
	54° 59!2 W.	8-XII -75		T/P	4,200	4,200	setting; Kevlar test cable
563	38° 29!8 N.	7-V -75	217	850	4,000	3,999	Mooring #9 of Array II, first
	54° 58!0 W.	9-XII -75		T/P	4,001	4,000	setting, Kevlar test cable
564	37° 29!5 N.	5-V -75	220	VACM	600	590	Mooring #8 of Array II, first
	55° 00!0 W.	10-XII -75		T/P	800	790	setting
				VACM	1,000	990	
				850	1,500	1,490	
				VACM	4,000	3,992	
565	35° 36!0 N.	8-V -75	225	VACM	600	646	Mooring #3 of Array II, first
	55° 05!0 W.	18-XII -75		T/P	800	846	setting
				VACM	1,000	1,046	
				850	1,500	1,546	
				T/P	3,000	3,045	
				VACM	4,000	4,046	
				T/P	5,000	5,046	

Summary, Continued

Sta. #	Lat & Long	Dates Set and Rec	Days Dur.	Instr. Type	Instr. Design Depth (m)	As Launched Zero Current Depth (m)	Remarks
566	34° 53!5 N. 55° 01!7 W.	9-V -75 17-XII -75	223	VACM T/P VACM 850 VACM	600 800 1,000 1,500 4,000	604 805 1,005 1,505 4,006	Mooring #5 of Array II, first setting
567	31° 35!9 N. 55° 05!0 W.	14-V -75 15-XII -75	216	VACM T/P VACM 850 VACM	600 828 1,000 1,500 4,000	628 828 1,028 1,528 4,030	Mooring #7 of Array II, first setting; titanium VACM parts
568	35° 55!8 N. 59° 01!7 W.	15-V -75 19-XII -75	219	VACM T/P VACM 850 VACM	600 800 1,000 1,500 4,000	599 800 1,000 1,500 4,001	Mooring #6 of Array II, first setting; Milliman samples attached along mooring line
573	41° 29!3 N. 54° 58!6 W.	7-XII -75 7-X -76	306	850 T/P	4,000 4,001	4,001 4,002	Mooring #12 of Array II, second setting
574	40° 27!1 N. 55° 03!0 W.	8-XII -75 9-X -76	307	850 T/P	4,000 4,200	3,995 4,195	Mooring #11 of Array II, second setting
575	39° 30!2 N. 54° 59!9 W.	8-XII -75 10-X -76	308	850 T/P	4,000 4,200	3,993 4,193	Mooring #10 of Array II, second setting
576	38° 29!6 N. 54° 55!4 W.	9-XII -75 10-X -76	307	850 T/P	4,000 4,001	3,997 3,998	Mooring #9 of Array II, second setting

Summary, Continued

Sta. #	Lat & Long	Dates Set and Rec	Days Dur.	Instr. Type	Instr. Design Depth (m)	As Launched Zero Current Depth (m)	Remarks
577	37° 28!7 N.	10-XII -75	308	VACM	600	588	Mooring #8 of Array II, second setting
	55° 01!0 W.	12-X -76		T/P	800	790	
				VACM	1,000	991	
				850	1,500	1,495	
				VACM	4,000	3,995	
578	35° 58!3 N.	11-XII -75	300	VACM	600	577	Mooring #4 of Array II, second setting
	53° 45!4 W.	5-X -76		T/P	800	779	
				VACM	1,000	980	
				850	1,500	1,483	
				VACM	4,000	3,985	
579	35° 55!7 N.	12-XII -75	298	VACM	600	590	Mooring #2 of Array II, second setting; mooring dragged while on station in a west-southwesterly direction about 8 miles
	54° 41!8 W.	4-X -76		T/P	800	792	
				VACM	1,000	994	
				850	1,500	1,497	
				T/P	3,000	2,992	
				VACM	4,000	4,000	
				T/P	5,000	5,001	
580	31° 35!2 N.	15-XII -75	310	VACM	600	587	Mooring #7 of Array II, second setting
	54° 56!0 W.	19-X -76		T/P	800	789	
				VACM	1,000	990	
				850	1,500	1,494	
				VACM	4,000	3,995	
581	34° 55!6 N.	17-XII -75	306	VACM	600	587	Mooring #5 of Array II, second setting
	55° 04.7 W.	17-X -76		T/P	800	789	
				VACM	990	1,000	
				850	1,500	1,494	
				VACM	4,000	3,995	

Summary, Continued

Sta. #	Lat & Long	Dates Set and Rec	Days Dur.	Instr. Type	Instr. Design Depth (m)	As Launched Zero Current Depth (m)	Remarks
582	35° 36!0 N.	18-XII -75	303	VACM	600	588	Mooring #3 of Array II, second
	55° 05!0 W.	15-X -76		T/P	800	790	setting; mooring dragged while
				VACM	1,000	991	on station in a westerly direct-
				850	1,500	1,495	ion about 3 miles
				T/P	3,000	2,988	
				VACM	4,000	3,996	
				T/P	5,000	4,996	
583	35° 52!5 N.	18-XII -75	302	VACM	600	605	Mooring #1 of Array II, second
	55° 02!5 W.	14-X -76		T/P	800	806	setting
				VACM	1,000	1,008	
				T/P	1,200	1,210	
				850	1,500	1,492	
				T/P	2,000	1,996	
				T/P	2,500	2,500	
				T/P	3,000	3,004	
				T/P	3,500	3,509	
				VACM	4,000	3,993	
				T/P	4,500	4,497	
				T/P	5,000	5,001	
584	35° 56!9 N.	20-XII -75	288	VACM	600	592	Mooring #6 of Array II, second
	59° 01!5 W.	2-X -76		T/P	800	795	setting
				VACM	1,000	996	
				850	1,500	1,499	
				VACM	4,000	4,000	
598	35° 55!3 N.	2-X -76	239	VACM	600	600	Mooring #6 of Array II, third
	59° 02!3 W.	28-V -77		T/D	800	800	setting
				VACM	1,000	1,000	
				850	1,500	1,500	
				VACM	4,000	4,000	
599	35° 57!4 N.	3-X -76	239	VACM	4,000	3,997	Mooring #15 of Array II, only
	55° 27!8 W.	29-V -77					setting

Summary, Continued

Sta. #	Lat & Long	Dates Set and Rec	Days Dur.	Instr. Type	Instr. Design Depth (m)	As Launched Zero Current Depth (m)	Remarks
600	35° 55'.3 N.	4-X -76	238	VACM	600	599	Mooring #2 of Array II, third setting
	54° 44'.4 W.	29-V -77		T/P	800	799	
				VACM	1,000	999	
				850	1,500	1,498	
				T/P	3,000	2,999	
				VACM	4,000	3,999	
				T/P	5,000	4,999	
601	35° 57'.5 N.	5-X -76	238	VACM	600	603	Mooring #4 of Array II, third setting
	53° 46'.9 W.	30-V -77		T/P	800	803	
				VACM	1,000	1,003	
				850	1,500	1,503	
				VACM	4,000	4,003	
602	41° 29'.4 N.	8-X -76	275	VACM	4,000	3,993	Mooring #12 of Array II, third setting
	54° 58'.0 W.	9-VII -77		T/P	4,001	3,994	
603	40° 27'.1 N.	9-X -76	273	VACM	4,000	3,996	Mooring #11 of Array II, third setting
	55° 03'.0 W.	8-VII -77		T/P	4,200	4,196	
604	39° 29'.2 N.	10-X -76	271	VACM	4,000	4,002	Mooring #10 of Array II, third setting
	55° 00'.8 W.	7-VII -77		T/P	4,200	4,202	
605	38° 28'.8 N.	11-X -76	268	VACM	4,000	4,003	Mooring #9 of Array II, third setting
	54° 56'.1 W.	5-VII -77		T/P	4,001	4,004	
				VACM	5,240	5,240	
				T/P	5,241	5,241	
606	37° 29'.3 N.	12-X -76	267	VACM	600	614	Mooring #8 of Array II, third setting
	54° 59'.6 W.	5-VII -77		T/P	800	814	
				VACM	1,000	1,014	
				850	1,500	1,513	
				VACM	4,000	4,013	

Summary, Continued

Sta. #	Lat & Long	Dates Set and Rec	Days Dur.	Instr. Type	Instr. Design Depth (m)	As Launched Zero Current Depth (m)	Remarks
607	36° 30!0 N.	13-X -76	265	VACM	650	647	Mooring #13 of Array II, only
	55° 00!0 W.	4-VII -77		VACM	1,050	1,048	setting
				VACM	1,550	1,548	
				VACM	4,050	4,047	
608	35° 52!8 N.	15-X -76	262	VACM	600	605	Mooring #1 of Array II, third
	55° 04!6 W.	3-VII -77		T/P	800	805	setting
				VACM	1,000	1,005	
				T/P	1,200	1,206	
				850	1,500	1,506	
				T/P	2,000	2,006	
				T/P	2,500	2,506	
				T/P	3,000	3,005	
				T/P	3,500	3,505	
				VACM	4,000	4,005	
				T/P	4,500	4,505	
				VACM	5,000	5,006	
609	35° 35!8 N.	15-X -76	262	VACM	600	600	Mooring #3 of Array II, third
	55° 04!8 W.	3-VII -77		T/P	800	800	setting
				VACM	1,000	1,000	
				850	1,500	1,500	
				T/P	3,000	3,000	
				VACM	4,000	4,000	
				Inv. Echo Sndr.	5,000	5,002	
				VACM	5,004	5,006	
				T/P	5,005	5,007	
610	35° 14!5 N.	14-X -76	261	VACM	600	598	Mooring #14 of Array II, only
	55° 00!0 W.	3-VII -77		VACM	1,000	999	setting; top VACM also records
				VACM	1,500	1,498	pressure changes (VACM-P)
				VACM	4,000	3,998	

Summary, Continued

Sta. #	Lat & Long	Dates Set and Rec	Days Dur.	Instr. Type	Instr. Design Depth (m)	As Launched Zero Current Depth (m)	Remarks
611	34° 55!5 N.	17-X -76	259	VACM	600	601	Mooring #5 of Array II, third
	55° 04!8 W.	2-VII -77		T/P	800	801	setting; Milliman samples at-
				VACM	1,000	1,001	tached along mooring line
				850	1,500	1,501	
				VACM	4,000	4,001	
612	31° 35!2 N.	19-X -76	246	VACM	600	603	Mooring #7 of Array II, third
	54° 56!0 W.	21-VI -77		VACM	800	803	setting; VACM at 950 m records
				T/P	801	804	differential temperatures
				VACM	950	953	(VACM-DT)
				VACM	1,000	1,003	
				VACM	1,500	1,503	
				VACM	2,000	2,002	
				VACM	2,500	2,503	
				VACM	4,000	4,003	
623	27° 24!8 N.	11-VI -77	350	VACM	200	128	Mooring #1 (central) of Array III,
	41° 07!7 W.	26-V -78		T/P	500	428	Cluster B; shallower instrument
				T/P	850	777	placement decided at sea before
				850	1,500	1,426	launch; bottom depth is 5,251 m
				T/P	2,800	2,727	
				T/P	3,400	3,327	
				850	4,000	3,927	
				T/P	Bottom - 6 m	4,245	
624	27° 17!5 N.	12-VI -77	348	T/P	200	229	Mooring #2 of Array III,
	40° 45!5 W.	25-V -78		850	500	529	Cluster B
				850	1,500	1,528	
				T/P	2,800	2,828	
				850	4,000	4,028	
625	27° 14!5 N.	12-VI -77	348	VACM	200	189	Mooring #3 of Array III,
	40° 21!1 W.	25-V -78		T/P	500	489	Cluster B
				850	1,500	1,488	
				T/P	2,800	2,790	
				850	4,000	3,990	

Summary. Continued

Sta. #	Lat & Long	Dates Set and Rec	Days Dur.	Instr. Type	Instr. Design Depth (m)	As Launched Zero Current Depth (m)	Remarks
626	26° 52!7 N. 41° 12!8 W.	13-VI -77 25-V -78	347	VACM T/P 850 T/P 850	200 500 1,500 2,800 4,000	215 515 1,514 2,815 4,015	Mooring #4 of Array III, Cluster B
627	26° 09!8 N. 41° 40!7 W.	14-VI -77 24-V -78	345	VACM T/P 850 T/P 850	200 500 1,500 2,800 3,400	206 506 1,505 2,806 3,407	Mooring #5 of Array III, Cluster B
628	27° 25!6 N. 47° 50!0 W.	16-VI -77 22-V -78	341	T/P 850 850 T/P 850	200 500 1,500 2,800 4,000	190 490 1,489 2,789 3,994	Mooring #2 of Array III, Cluster A; ORE sphere for top flotation
629	28° 01!0 N. 48° 03!3 W.	17-VI -77 22-V -78	340	VACM T/P 850 T/P 850	200 500 1,500 2,800 4,000	203 501 1,500 2,801 4,006	Mooring #3 of Array III, Cluster A
630	27° 51!7 N. 48° 39!4 W.	17-VI -77 21-V -78	339	VACM T/P T/P 850 T/P T/P 850 T/P	200 500 850 1,500 2,800 3,500 4,000 Bottom - 6 m	200 499 848 1,498 2,798 3,498 4,003 4,889	Mooring #1 (central) of Array III, Cluster A; time capsule at 4,500 m; bottom depth is 4,895 m

Summary, Continued

Sta. #	Lat & Long	Dates Set and Rec	Days Dur.	Instr. Type	Instr. Design Depth (m)	As Launched Zero Current Depth (m)	Remarks
631	27° 55'.9 N.	18-VI -77	338	VACM	200	212	Mooring #4 of Array III,
	48° 52'.1 W.	21-V -78		T/P	500	511	Cluster A
				850	1,500	1,510	
				T/P	2,800	2,811	
				850	4,000	4,016	
632	26° 51'.8 N.	18-VI -77	337	VACM	200	190	Mooring #5 of Array III,
	49° 13'.5 W.	20-V -78		T/P	500	489	Cluster A
				850	1,500	1,488	
				T/P	2,800	2,789	
				850	4,000	3,993	
638	31° 23'.1 N.	29-IV -78	448	T/P	500	501	L.D.E. Mooring #7
	69° 28'.9 W.	20-VII -79		VACM	600	602	
				T/P	700	702	
639	31° 09'.8 N.	30-IV -78	448	T/P	500	498	L.D.E. Mooring #2
	69° 22'.0	21-VII -79		VACM	600	599	
				T/P	700	698	
				VACM	825	822	
640	31° 01'.4 N.	30-IV -78	449	VACM	250	245	L.D.E. Mooring #1 (central);
	69° 29'.9 W.	22-VII -79		VACM	375	370	VACM @ 370 m records pressure
				VACM	500	494	(VACM-P); three Gardner sediment
				VACM	600	595	traps on mooring; bottom depth
				VACM	700	695	5,355 m
				VACM	825	820	
				T/P	925	920	
				850	1,050	1,044	
				850	1,275	1,270	
				850	2,000	1,995	
				850	3,000	2,995	
				VACM	Bottom - 100 m	5,250	
				Tens'meter	Bottom - 99 m	5,251	
				VACM	Bottom - 15 m	5,332	

Summary, Continued

Sta. #	Lat & Long	Dates Set and Rec	Days Dur.	Instr. Type	Instr. Design Depth (m)	As Launched Zero Current Depth (m)	Remarks
641	31° 10!1 N.	30-IV -78	449	VACM	600	595	L.D.E. Mooring #3
	69° 37!5 W.	22-VII -79		T/P	700	695	
				VACM	825	819	
642	30° 58!5 N.	1-V -78	448	T/P	500	502	L.D.E. Mooring #8
	69° 50!0 W.	22-VII -79		VACM	600	603	
				T/P	700	703	
643	30° 49!1 W.	10-V -78	440	T/P	500	510	L.D.E. Mooring #4
	69° 36!8 W.	23-VII -79		VACM	600	611	
				T/P	700	710	
				VACM	825	834	
644	30° 35!5 N.	10-V -78	441	T/P	500	543	L.D.E. Mooring #9
	69° 28!2 W.	24-VII -79		VACM	600	644	
				T/P	700	743	
645	31° 00!7 N.	10-V -78	?	VACM	275	274	L.D.E. Mooring #10; VACM @ 275 m records pressure (VACM-P); no acoustic contact during recovery, search pattern conducted, drag-operations performed
	69° 27!0 W.	Lost		VACM	400	399	
				T/P	525	524	
				VACM	625	624	
				T/P	725	724	
				VACM	850	849	
				VACM	1,525	1,524	
				850	4,025	4,024	
646	30° 50!3 N.	11-V -78	439	TP	500	492	L.D.E. Mooring #5
	69° 22!0 W.	23-VII -79		VACM	600	593	
				TP	700	693	
				VACM	800	817	

Summary, Continued

Sta. #	Lat & Long	Dates Set and Rec	Days Dur.	Instr. Type	Instr. Design Depth (m)	As Launched Zero Current Depth (m)	Remarks
647	31° 00!0 N.	11-V -78	439	T/P	500	477	L.D.E. Mooring #6
	69° 09!6 W.	23-VII -79		VACM	600	578	
				T/P	700	677	
648	27° 51!4 N.	27-V -78	515	VACM	200	178	Array III, Cluster A site mooring; longest mooring duration to date for WHOI Buoy Group
	48° 40!9 W.	18-X -79		T/P	500	478	
				T/P	850	828	
				VACM	1,500	1,479	
				T/P	2,800	2,779	
				T/P	3,500	3,478	
				VACM	4,000	3,978	
649	27° 25!6 N.	26-V -78	513	VACM	200	216	Array III, Cluster B site mooring; the end
	41° 09!4 W.	20-X -79		T/P	500	516	
				T/P	850	866	
				850	1,500	1,517	
				T/P	2,800	2,818	
				T/P	3,400	3,417	
				VACM	4,000	4,018	

Appendix III

WHOI Mooring Operations Summary

of Other Buoy Group Moorings of Interest to POLYMODE Investigators

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VACM = Vector Averaging Current Meter

850 = EG&G Current Meter

T/P = Temp./Press. Recorder (MIT)

Sta. #	Lat & Long	Dates Set and Rec	Days Dur.	Instr. Type	Instr. Design Depth (m)	As Launched Zero Current Depth (m)	Remarks
553	31° 46'.9 N.	28-IV -75	274	VACM	300	306	Mooring #2 of Nelson Hogg's Bermuda Microstructure Array; VACM at 500 m records differential temperatures (VACM-DT)
	64° 26'.2 W.	26-I -76		VACM	500	506	
				T/P	720	725	
				VACM	1,000	1,005	
				850	1,500	1,505	
554	32° 21.5 N.	29-IV -75	273	VACM	300	314	Mooring #1 of Microstructure Array
	65° 27.0 W.	26-I -76		VACM	500	514	
				T/P	720	733	
				VACM	1,000	1,013	
				850	1,500	1,513	
555	32° 59'.0 N.	29-IV -75	272	VACM	300	316	Mooring #3 of Microstructure Array; two top VACMs record differential temperatures (VACM-DT)
	64° 23'.8 W.	25-I -76		VACM	500	516	
				T/P	720	736	
				VACM	750	766	
				VACM	1,000	1,016	
				850	1,500	1,516	
				850	4,000	4,016	

Sta. #	Lat & Long	Dates Set and Rec	Days Dur.	Instr. Type	Instr. Design Depth (m)	As Launched Zero Current Depth (m)	Remarks
556	33° 21'.1 N.	30-IV -75	18	850	1,300	1,329	Deep water circulator instrument for Sus Honjo
	64° 06'.3 W.	17-V -75		Circulator	4,400	4,424	
615	31° 32'.7 N.	8-I -77	166	VACM	600	559	Internal Wave Self Interaction mooring for Mel Briscoe and Terry Joyce; T/Ps also record conductivity; top VACM is VACM-p; VACMs at 773 m and 775 m are VACM-DTs
	54° 58'.7 W.	22-VI -77		T/P	768	766	
				T/P	769	767	
				VACM	773	771	
				VACM	775	773	
				VACM	779	778	
				VACM	821	819	
				VACM	825	824	
				VACM	827	826	
				VACM	1,000	999	
616	30° 54'.9 N.	14-V -77	357	VACM	2,000	1,995	Mooring #1 of Western Boundary Undercurrent (W.B.U.C) array for Peter Rhines; top VACM also records pressure changes (VACM-p)
	76° 39'.0 W.	5-V -78		T/P	2,001	1,996	
				VACM	2,800	2,796	
617	30° 32'.1 N.	14-V -77	358	VACM	600	601	Mooring #2 of W.B.U.C.; VACM at 600 m is VACM-p
	75° 06'.0 W.	5-V -78		VACM	2,000	2,002	
				VACM	3,600	3,602	
618	30° 43'.2 N.	15-V -77	354	VACM	2,000	2,002	Mooring #3 of W.B.U.C.; VACM at 2,000 m is VACM-p
	74° 11'.0 W.	3-V -78		VACM	3,000	3,003	
				VACM	3,800	3,802	
619	30° 48'.3 N.	15-V -77	?	VACM	600	596	Mooring #4 of W.B.U.C.; VACM at 2,000 m is VACM-p; no acoustic contact during recovery; extensive search patterns were conducted
	74° 00'.5 W.	Lost		VACM	2,000	1,997	
				T/P	2,001	1,998	
				VACM	3,000	2,996	
				VACM	4,400	4,396	
620	31° 03'.5 N.	15-V -77	353	VACM	2,000	1,958	Mooring #5 of W.B.U.C.; VACM at 2,000 m is VACM-p
	73° 28'.8 W.	2-V -78		VACM	3,000	2,958	
				VACM	5,000	4,987	

Sta. #	Lat & Long	Dates Set and Rec	Days Dur.	Instr. Type	Instr. Design Depth (m)	As Launched Zero Current Depth (m)	Remarks
621	28° 31!0 N. 70° 28!5 W.	17-V -77 18-VIII-77	94	VACM VACM VACM VACM VACM VACM VACM	Bottom - 85 m Bottom - 65 m Bottom - 55 m Bottom - 45 m Bottom - 35 m Bottom - 25 m Bottom - 15 m	5,368 5,388 5,398 5,408 5,418 5,428 5,438	Mooring #1 of Benthic Boundary Layer experiment for Larry Armi; all VACMs except top one record differential temperature (VACM-DT); bottom depth is 5,453 m
622	28° 31!0 N. 70° 24!8 W.	18-V -77 18-VIII-77	93	VACM	Bottom - 35 m	5,418	Mooring #2 of Benthic Boundary Layer experiment; bottom depth is 5,453 m
633	32° 33!8 N. 64° 44!7 W.	15-XI -77 7-XII -78	388	VACM VACM VACM VACM	600 900 1,200 1,500	611 911 1,211 1,511	Mooring #2 of Nelson Hogg's Island Trapped Waves experiment; released prematurely, recovered from reef by Bermuda Biostation. Top VACM is VACM-p
634	32° 32!2 N. 64° 44!1 W.	16-XI -77 16-XII -78	396	T/P VACM VACM	300 600 900	242 542 842	Mooring #1 of Island Trapped Waves experiment
635	32° 22!4 N. 65° 00!9 W.	17-XI -77 17-XII -78	396	T/P VACM VACM	300 600 900	224 524 824	Mooring #3 of Island Trapped Waves experiment
636	04° 02!5 N. 39° 40!6 W.	8-XII -77 5-XII -78	363	VACM 850 VACM VACM	Bottom - 200 m Bottom - 100 m Bottom - 50 m Bottom - 10 m	4,256 4,356 4,406 4,446	Mooring #1 of Val Worthington's Western Basin Sill experiment; bottom depth 4,456 m
637	04° 01!3 N. 39° 19!0 W.	8-XII -77 5-XII -78	363	VACM 850 VACM VACM	Bottom - 200 m Bottom - 100 m Bottom - 50 m Bottom - 10 m	4,104 4,204 4,254 4,294	Mooring #2 of Western Basin Sill experiment; bottom depth 4,304 m

Sta. #	Lat & Long	Dates Set and Rec	Days Dur.	Instr. Type	Instr. Design Depth (m)	As Launched Zero Current Depth (m)	Remarks
650	38° 03'.2 N.	3-VI -78	200	Incln'meter	471	470	Gulf Stream Engineering mooring
	68° 56'.4 W.	20-XII -78		Depth Rec.	473	472	for Bob Walden
				Niskin C.M.	475	474	
				Temp. Rec.	477	476	
				Incln'meter	1,196	1,209	
				Depth Rec.	1,198	1,211	
				Niskin C.M.	1,200	1,213	
				Temp. Rec.	1,202	1,215	
673	37° 00'.1 N.	23-X -79	400	VACM-P	500	526	Gulf Stream Extension/Norwegian
	42° 00'.4 W.	25-XI -80		T/P	800	826	Sea Overflow Experiment, mooring
				850	1,500	1,526	#8.
				850	4,000	4,026	
674	39° 46'.1 N.	25-X -79	396	VACM-P	500	523	GSE/NSOE, mooring #6.
	43° 56'.9 W.	23-XI -80		T/P	800	822	
				850	1,500	1,523	
				850	4,000	4,023	
675	40° 22'.0 N.	26-X -79	394	VACM-P	500	530	GSE/NSOE, mooring #1.
	45° 19'.9 W.	22-XI -80		T/P	800	829	
				VACM-P	1,500	1,530	
				850	4,000	4,031	
676	39° 03'.0 N.	29-X -79	393	VACM-QT	Bottom - 181 m	4,658	GSE/NSOE, mooring #4. QT = 4
	44° 02.0 W.	24-XI- -80		VACM-QT	Bottom - 141 m	4,697	temperature sensors spaced along
				VACM-QT	Bottom - 91 m	4,747	mooring line. *Neil Brown
				VACM-QT	Bottom - 61 m	4,779	acoustic current meter
				VACM-QT	Bottom - 11 m	4,829	
				*CM	Bottom - 10 m	4,830	

Sta. #	Lat & Long	Dates Set and Rec	Days Dur.	Instr. Type	Instr. Design Depth (m)	As Launched Zero Current Depth (m)	Remarks
677	38° 58!4 N.	30-X -79	392	VACM-PI	500		GSE/NSOE, mooring #3. VACM-PI records also pressure and inclination. *Neil Brown acoustic current meter
	44° 06!6 W.	24-XI -80		T/P	800		
				VACM-PI	1,500		
				VACM	4,000		
				VACM-QT	Bottom - 190 m		
				VACM-QT	Bottom - 110 m		
				VACM-QT	Bottom - 30 m		
				*CM	Bottom - 10 m		
678	38° 40!7 N.	31-X -79	389	VACM-P	500	491	GSE/NSOE, mooring #7
	45° 37!4 W.	22-XI -80		T/P	800	791	
				850	1,500	1,491	
				850	4,000	3,989	
				VACM-QT	Bottom - 110 m	4,835	
				VACM-QT	Bottom - 30 m	4,915	
679	37° 58!5 N.	1-XI -79	387	VACM-P	500	506	GSE/NSOE, mooring #5
	46° 38!0 W.	21-XI -80		T/P	800	806	
				VACM-P	1,500	1,504	
				850	4,000	4,003	
680	38° 52!5 N.	1-XI -79	386	VACM-P	500	512	GSE/NSOE, mooring #2
	46° 54.5 W.	20-XI -80		T/P	800	812	
				VACM-P	1,500	1,512	
				850	4,000	4,013	

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The Woods Hole Oceanographic Institution Buoy Group's field work for the international POLYMODE program consisted of deployment and recovery of seventy of the seventy-eight program moorings on eight research cruises. The mooring program consisted of four distinct experiments conducted from June of 1974 to November of 1979. A brief discription of the arrays is provided, the mooring design process for a typical POLYMODE mooring is explained, and brief summaries are given of the WHOI deployment and recovery cruises. Appendix I is a schematic presentation of the chronological mooring history. Appendix II lists details of the seventy WHOI moorings deployed in the POLYMODE program and Appendix III lists details of other WHOI moorings that may be of interest to investigators.

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3. Current meters

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